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ESTABLISHING A NEW STATE-OF-THE-ART LIFE SCIENCE RESEARCH INSTITUTE: DEFINING KEY COLLABORATIONS

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Abstract

The newly founded Nova Institute for Medical Systems Biology (NIMSB) in Portugal aims to establish itself as a leading institute in the field of medical systems biology. This project focuses on exploring the challenges and opportunities associated with four key conceptual pillars of NIMSB: local partnerships, biobanks, clinical trials, and industry collaborations. Findings from 45 interviewees and additional research were analyzed to identify primary strategies for the Institute related to these components.

At the core of NIMSB's mission there is among others the establishment of a strong local and global partnership network crucial for its integration into the scientific ecosystem. This thesis offers strategic guidance for these key collaborations, focusing on tailored models to leverage partnerships and address challenges. Practical recommendations include prioritizing marketing, workforce development, and strategic partnerships with hospitals, biobanks, and industry stakeholders to enhance research capacity and societal impact.

Keywords: Research Organizations, Systems Biology, Innovation, Biobanks, Clinical Trials, Key Collaborations, Industry Partnerships

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Establishing a New State-of-the-art Research Institute: The NIMSB (Group Part)....4
Section A: Defining Key Collaborations (Group Part)....6
1. Collaboration: A Catalyst for Research Excellence....7
1.1. Relevance of Collaboration....7
1.2. Types of Research Collaborations....8
1.3. International Best Practices....9
2. NIMSB's Ecosystem: Needs and Opportunities for Collaboration (Group Part).... 10
2.1. Resource Needs (Group Part)....10
2.2. Educational Needs (Group Part)....11
2.3. Marketing Needs (Group Part)....12
2.4. Opportunities for Biobanking (Group Part)....12
2.5. Opportunities for Clinical Trials (Group Part)....13
2.6. Industry Opportunities (Group Part)....13
2.7. Regulatory Needs (Group Part)....14
3. Available Capabilities (Group Part)....15
3.1. Internal Capabilities (Group Part)....15
3.2. Cross-Functional Capabilities (Group Part)....16
3.3. External Capabilities (Group Part)....17
4. Suggested Collaboration Models: Becoming a State-of-the-art Life Science Institute....20
4.1. Collaborative Research Projects Suggested Partnerships for Ensured Mutual Resource Sharing 20
4.1.1. Potential Partnerships....21
4.2. Joint Training and Trend Scouting....25
4.2.1. Potential Partnerships....25
4.3. Strategic Marketing Partnerships....28
4.3.1. Potential Partnerships....28
4.4. Other Types of Collaborations....30
5. Practical Recommendations (Group Part)....30
Section B: Opportunities and Barriers of Biobanking (Group Part)....32
1. Value Creation and Impact Generation Through Biobanks (Group Part)....33
1.1. The Medical Perspective (Group Part)....34
1.2. The Scientific Perspective (Group Part)....35
1.3. The Commercial Perspective (Group Part)....36
1.3.1. Challenges of a Centralized Biobanking Model (Group Part)....37
2. Strategic Insights and Recommendations for Biobanking for the NIMSB (Group Part)....40
2.1. Structured and Ethical Sample Management Through Shared Resources (Group Part)....41
2.2. Stronger Collaboration and Better Sample Acquisition (Group Part)....42
2.3. Improving Sustainability and Funding (Group Part)....43
2.4. Ensuring Impact Generation (Group Part)....43
3. Conclusion (Group Part)....44

Section C: A Blueprint for Clinical Trial Contribution (Group Part)....44
1.1. Exploring Additional Potential Contributions of the NIMSB to Clinical Trials (Group Part). 45
1.1.1. Training and Educational Initiatives (Group Part)....46
1.1.2. Management of Clinical Trial and Data (Group Part)....46
1.1.3. Patient-Centric Approaches (Group Part)....47
1.1.4. Science-Based Venture Building (Group Part)....47
2. NIMSB´s Strategic Benefits for Clinical Trial Support (Group Part)....48
2.1. Collaboration and Resource Access (Group Part)....48
2.2. Innovation and Revenue Generation (Group Part)....49
2.3. Enhancing Patient Outcomes and Credibility (Group Part)....50
3. Practical Recommendations (Group Part)....50
Section D: Forging Ties with Industry (Group Part)....53
1. The Importance of Collaboration Between Research and Industry (Group Part)....54
2. NIMB'S Vision, Capabilities, and Objectives (Group Part)....55
2.1. Partnership Scope Selection Process (Group Part)....56
2.1.1. The Impact of Spinouts beyond the NIMSB (Group Part)....57
2.1.2. Dual Communication Models (Group Part)....58
3. Challenges (Group Part)....59
4. Practical Recommendations (Group Part)....59
Final Conclusion (Group Part)....62
References....64
Appendices....70
Appendix 1: List of Abbreviations....70
Appendix 2: Definitions....72
Appendix 3: Method....74
Identification and Recruitment of Participants....74
Interview Structure and Process....74
Appendix 4: Conducted Interviews....75
Appendix 5: The BIMSB's Ecosystem....80
Local Collaborations....80
National Collaborations....81
International Collaborations....81
Appendix 6: IRBS's Ecosystem....82
National Collaborations....82
International Collaborations....82
Appendix 7: Other Types of Collaborations....83
Appendix 28: The House of NIMSB....86

Establishing a New State-of-the-art Research Institute: The NIMSB (Group Part)

With 6 million new cases and 1.8 million deaths related to cardiovascular disease, and 2.7 and 1.3 million cancer diagnoses and deaths, respectively, chronic diseases are a major health, societal, and economic burden in the European Union (EU) (European Commission 2022; European Heart Network 2017). As the population ages, the challenge of managing chronic diseases becomes increasingly difficult, endangering the long-term viability of healthcare systems. The Nova Institute for Medical Systems Biology (NIMSB) is a newly founded, independent Center of Excellence (CoE) for Medical Systems Biology located in Oeiras, near Portugal´s capital city, Lisbon. It will research, identify, and prevent diseases by developing and implementing cutting-edge molecular profiling technologies. New diagnostic and therapeutic approaches focusing on diseases with high morbidity and mortality rates, such as (henceforth s.a.) cardiovascular, neurodegenerative, and cancer, will be key outcomes of research and innovation activities at the NIMSB. Its main objectives include (1) developing an excellent research program in Medical Systems Biology focused on single-cell multi-omics, human disease models (including organoids), and AI for health, (2) contributing to improving human health outcomes through precision and interceptive medicine, and (3) training a new generation of researchers and medical doctors in advanced digital-transformation technologies. The institute recently raised a funding of EUR 30 million, with equal contributions from Horizon 2020 as well as from national and regional funds from the Ministry of Science, Oeiras and Cascais city councils, and the greater Lisbon regional authority. These funds primarily aim to ensure the successful establishment of the NIMSB to

meet its long-term objectives. A grant of this magnitude for a Portuguese research institution reflects the distinctiveness and the groundbreaking potential NIMSB's research may have. Moreover, it allows the rare and unique opportunity for this work to undertake an analysis from a foundational, ground-zero perspective.

As part of the Horizon 2020 program, the NIMSB has teamed up with the Max Delbrück Center for Molecular Medicine (MDC) in Berlin, a major biomedical research institution within the Helmholtz Association, which is the largest national research community in Germany. The MDC is also home to the renowned Berlin Institute for Medical Systems Biology (BIMSB), a leader in applying cutting-edge molecular, cellular, and computational technology to health concerns, which will serve as a model for the NIMSB in terms of research objectives. Since the initiation of the project, the director of the new institute, Prof. António Jacinto, and his team closely collaborated with representatives of the MDC, s.a. the BIMSB director, Nikolaus Rajewsky, Dr. Stan Gorski, and others. Thereby, the NIMSB has and will further benefit from the MDC's expertise and experience in establishing the BIMSB, cutting-edge technology infrastructure, relationships with hospitals, and innovation, education, and training initiatives. The complementary skills and objectives of this partnership assist the NIMSB to remain viable and increase its global influence.

Following its inaugural meeting in October 2023, the NIMSB's development continues to progress. While precise objectives were defined, as previously stated, there are still specific components of the institute that require further refinement and elaboration to fully comprehend their potential contribution to the long-term sustainability of the institute. Four key components were defined in active collaboration with the Director of the NIMSB and our supervisor, Prof. Nuno Arantes-Oliveira, that require further investigation: (1) local collaborations, (2) biobanking, (3) clinical trials, and (4) industry collaborations. While there

may be other crucial components, the rationale behind this selection derives from the examination of other prosperous global life science research institutes and the recognition that these components may collectively catalyze the NIMSB´s long-term sustainability and establish the NIMSB as an institute of excellence.

For each of these areas, the aim was to examine their unique opportunities and challenges in supporting NIMSB´s mission and objectives while simultaneously adding value to the broader research community. Additionally, the articulation of strategic and practical recommendations will lay a foundational framework, serving as a precursor to further investigation and the formulation of a comprehensive business plan. This thesis will introduce and discuss each topic sequentially to comprehensively understand their role in supporting the NIMSB´s long-term vision and contribution. The methodology is attached in Appendix 3 and an overview of all conducted interviews can be found in Appendix 4.

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Section A: Defining Key Collaborations (Group Part)

At the core of the NIMSB's mission is the creation of strong partnerships, vital for its integration into the scientific ecosystem. Recognizing the significance of this task, this thesis commits to delivering a strategic blueprint for these essential collaborations, aiming to facilitate the NIMSB's successful engagement within the research community. This includes a thorough investigation of the essential needs of the NIMSB and how distinct models of

collaboration can fulfill these requirements to enhance its research capacity. The analysis will give a clear picture of the research institutes's objectives, the operational landscape, and the resources available. It outlines customized collaboration models intended to leverage potential partnerships and expected synergies while tackling foreseeable challenges. The findings of this project aim to provide a strong base for the NIMSB, offering concrete theoretical guidance and practical strategies during its early stages. It seeks to identify the crucial initial steps for establishing a strong network of stakeholders. Ultimately, it will lay the foundation for the NIMSB's objectives to become an excellent research program in Medical Systems Biology, contribute to improving human health outcome, and offer training in advanced digital-transformation technologies (see detailed objectives in the introductory chapter).

1. Collaboration: A Catalyst for Research Excellence

To propose effective collaborations for the NIMSB, it is essential to outline the importance of partnerships, their existing types, and best practices from other research institutions. This helps in recommending strategically impactful partnerships for the NIMSB and meeting the evolving requirements of the research landscape.

1.1. Relevance of Collaboration

Working collaboratively and establishing a network in science is vital as it can forge valuable synergies (McClellan 2023, 1). The benefits highlight the relevance of partnerships:

(1) ***Enhancing quality:*** Bringing various stakeholders together fosters the exchange of expertise and skills. These different perspectives and approaches support complex problem-solving and increase the quality of outcomes (Rogers 2012, 23).

(2) ***Fostering innovation:*** Promoting discourse among partners can boost creativity and thus facilitate innovative and ground-breaking results (Dusdal and Powell 2021, 18).

(3) ***Increasing efficiency:*** Collaboration allows increasing productivity through shared responsibilities and resources, s.a. technology, facilities, and funding (Proulx, Hager, and Klein 2014, 1).

(4) ***Establishing reputation:*** Working with an already recognized organization can improve the reputation of an institution and thereby facilitate access to a new ecosystem of resources (Nyström et al. 2018, 11).

1.2. Types of Research Collaborations

The ground zero timing and the current status of the NIMSB offer a unique opportunity to critically evaluate the global collaboration landscape. Research institutes can engage in collaborations with individuals, teams, departments, and organizations from research institutes, hospitals, academia, and industry operating in similar or intersecting fields (Goldman 2012, 420; Katz and Martin 1997, 16). Alliances can be established both nationally and internationally (Cao and Wang 2021, 1). Furthermore, institutions or experts from diverse fields collaborate in interdisciplinary research, leveraging their unique strengths to tackle research challenges collectively (Stokols et al. 2003).

1.3. International Best Practices

Science necessitates cooperation for its success; therefore, developing valuable collaborations by analyzing global best practices from similar institutes is beneficial. As already mentioned, the BIMSB is acknowledged as a prime example for the NIMSB because of its similar research focus, its research excellence, and relevant network (Max Delbrück Center 2023; Jacinto, interview, September 29, 2023). Therefore, the BIMSB's collaborative research ecosystem will be analyzed in more detail. Another blueprint of the NIMSB, the Institute for Research in Biomedicine in Barcelona (IRB), will be examined due to its effective partnerships and comparable size (IRB Barcelona 2023; Santos, interview, November 14, 2023). A detailed analysis of the collaborations of each of these institutes is added in Appendix 5 and 6, respectively.

The international best practices demonstrate that research institutions function in a global network, highlighting the necessity for the NIMSB to concentrate on establishing effective and sustainable collaborations with key entities and stakeholders. Moreover, the proximity to renowned universities and hospitals appears to be an important condition for collaboration. Besides, the findings indicate that support from the powerful authorities is essential. Additionally, reflecting on the substantial contributions of both research institutes, the NIMSB may also explore adopting various responsibilities, s.a. educating new researchers to enrich the ecosystem. Divers and international alliances are fundamental in enabling the NIMSB to reach its objectives successfully.

2. NIMSB's Ecosystem: Needs and Opportunities for Collaboration (Group Part)

The international best practices highlight the significance of establishing a diverse local, national, and global partnership network. To transfer these insights and identify strategically beneficial collaborations for the NIMSB, it is imperative to examine the research institute's needs and available resources. These are derived from the goal of reaching the NIMSB's pre-defined objectives (Jacinto, interview, September 29, 2023). The following paragraph outlines the primary needs of the NIMSB, which arise from the interview insights aligned with the described objectives.

2.1. Resource Needs (Group Part)

Required resources to establish a research ecosystem range from specific expertise, human resources, and sufficient funding to cutting-edge technologies. Attracting employees and building specialized expertise is particularly important to address complex research issues (Crespo, interview, October 10, 2023; Dìas, interview, October 12, 2023; Gomes, interview, October 27, 2023; Gorski, interview, October 11, 2023; Jacinto, interview, September 29, 2023). This is especially relevant for the NIMSB, given its focus on precision medicine and AI, which involve demanding tasks, s.a. analyzing big data and developing complex algorithms (Kennedy, interview, October 13, 2023; Leite, interview, October 18, 2023). Furthermore, it became evident that attracting key opinion leaders (KOLs) is essential due to their significant contributions to research. Recruitment is specifically challenging for areas of computer science and artificial intelligence (Dìas, interview, October 12, 2023). Potential

underlying reasons stem from poor payment and strong competition among large companies when hiring employees. Thus, funding is required to provide attractive compensation to the staff (Dìas, interview, October 12, 2023; Gorski, interview, October 11, 2023). To retain qualified employees with competitive pay, a sense of belonging and overall employee satisfaction should be ensured (Crespo, interview, October 10, 2023; Dìas, interview, October 12, 2023). Pooling capacities between institutions can be useful for gathering skilled human capital (Agostinho, interview, October 24, 2023; Dìas, interview, October 12, 2023). Moreover, to lead groundbreaking research projects on early disease detection, the NIMSB must combine cutting-edge technologies, including (henceforth incl.) single-cell multi-omics, artificial intelligence, and disease models derived from patient data (Jacinto, interview, September 29, 2023). Enabling all required resources will thus demand substantial financial investment, which represents another crucial element of resources.

2.2. Educational Needs (Group Part)

To gain relevance within the research ecosystem and to meet the above-stated goal of training a new generation of researchers, the NIMSB needs to contribute in areas s.a. training and education. Therefore, the establishment of a Career, Education, and Training Office (CTO) and educational initiatives for researchers and clinicians are needed. Additionally, integrative education through close collaboration with the university may foster education synergies. A workforce demand was primarily identified in data science, bioinformatics, multi-omics analytics, and AI designed explicitly for use in biomedical and clinical settings (Jacinto, interview, September 29, 2023). Moreover, researchers at the NIMSB should be trained to effectively present the institute's strengths and research findings to the public, as

many are not naturally skilled in this due to a focus on scientific pursuits (Leal, interview, October 19, 2023). As per section D, such training and education may also encompass teaching blocks within business and entrepreneurship to foster translational research.

2.3. Marketing Needs (Group Part)

According to the interviewees, the NIMSB should focus on raising awareness to attract different companies and partners. A crucial step in establishing a reputation is implementing a strong marketing strategy. The NIMSB's capabilities need effective local and international marketing to attract potential partners (Gomes, interview, October 27, 2023; Leal, interview, October 19, 2023). Communicating the NIMSB's value proposition among institutes is vital to identifying complementary stakeholders and working together efficiently. However, frequent communication problems among research institutions in Portugal were pointed out during the interviews (Gomes, interview, October 27, 2023). The lack of communication among organizations represents a challenge but can also be considered as an opportunity for improvement.

2.4. Opportunities for Biobanking (Group Part)

The decision on what biobanking format the NIMSB will engage and to what extent depend on external resources and still needs to be evaluated (Section B). However, collecting samples will be crucial for conducting research and sample analysis on a molecular level (Leal, Interview, October 19, 2023). Regardless of the advised model of biobanking, beneficial collaborations should be initiated with stakeholders, enabling or ensuring sufficient and diverse sample availability (Gorski, Interview, October 11, 2023). Additionally, expertise

regarding the implementation of robust quality protocols, legal frameworks, and extensive organizational efforts, accompanied by sufficient financial resources, will be needed (Dìas, interview, October 12, 2023; Kennedy, interview, October 12, 2023; Leal, interview, October 19, 2023; Ng, interview, October 25, 2023). Further needs, opportunities, and challenges in terms of biobanking and sample collection for the NIMSB will be discussed in section B, “Biobanks”.

2.5. Opportunities for Clinical Trials (Group Part)

Considering participation in clinical trials is crucial to the NIMSB as these trials are key to translating research findings into real patient benefits. Engaging in this area is critical to connecting with key stakeholders, including hospitals and pharmaceutical companies (Kennedy, interview, October 13, 2023; Leite, interview, October 18, 2023). Such involvement not only broadens the reach and deepens the research of the NIMSB but also brings mutual benefits. This focus would demonstrate the NIMSB's commitment to bridging the gap between research and practical application and reinforces the NIMSB's role as a key player in the healthcare research community. In-depth insights into the fundamentals, strategies, and benefits of clinical trials are explained in section C, “Clinical Trials”.

2.6. Industry Opportunities (Group Part)

Successful research outcomes require engagement with the industry (Crespo, interview, October 10, 2023; Gorski, interview, October 11, 2023). Collaborating with companies is intended to strengthen the reputation of an institute and boost funding.

Furthermore, translating research results into marketable solutions eventually leads to the founding of start-ups, spinouts, and the formation of licensing agreements (Benz, interview, October 13, 2023; Gomes, interview, October 27, 2023; Leal, interview, October 19, 2023). In addition, job creation and advances in healthcare can increase the likelihood of governmental support (Leal, interview, October 19, 2023). Therefore, research institutes should actively approach companies, recognize their needs, and promote mutually beneficial synergies (Gorski, interview, October 11, 2023; Kolben, interview, October 17, 2023; O'Beirne, interview, November 16, 2023). Further information on this topic can be found in section D, "Industry Collaborations".

2.7. Regulatory Needs (Group Part)

Technology transfer (TT) involves a number of legal aspects, s.a. patent registration and intellectual property (IP) negotiations (Benz, interview, October 13, 2023). Additional information on the topic of industry engagement, incl. intellectual property and patents, is illustrated in Section D. Moreover, as already indicated, specific legal conditions apply to biobanking, and clinical trials require specialized legal support. Besides, many scientists lack the expertise to market their research findings, hindering the successful development of products (Gomes, interview, October 27, 2023). To reduce disagreements within research, it is important to seek advice on legal issues, especially regarding IP sharing (Dìas, interview, October 12, 2023; Gorski, interview, October 11, 2023; Kennedy, interview, October 13, 2023). To function effectively within a research environment, the institutes should foster trust by offering an innovative and properly structured working environment by providing legal frameworks (Dìas, interview, October 12, 2023).

Undoubtedly, being at ground zero, the NIMSB will encounter challenges in building impactful collaborations. The groups of needs and opportunities critical for success that have been identified include resources (human resources, expertise, technology, funding, etc.), education, marketing and communication, industry engagement, legalities, and economic and social value creation. Focusing on the three components, namely effective communication, qualified human resources, and sustainable financial resources, will allow the NIMSB to prioritize its efforts strategically in the early stage to lay the foundation for achieving its objectives. In addition, participation in clinical trials, biobanking, and active industry engagement are crucial for promoting research excellence and impacting the health community, necessitating substantial efforts.

3. Available Capabilities (Group Part)

To effectively analyze what collaborations are key for success, besides illustrating the NIMSB's needs, it is crucial to highlight the available resources that serve as the institute's building block. These were mainly identified through interviews with the NIMSB's director and additional official internal documents.

3.1. Internal Capabilities (Group Part)

The NIMSB will provide diverse capabilities to the ecosystem, s.a. expertise, scientific approaches, data sets, services, and technologies. The establishment of the research institute will increase the critical mass of researchers and technicians by 300 people. The institute will set up 20 research groups with 12 principal investigators. Half of the NIMSB's capacity is expected to be used for laboratory experiments and the remaining half for data analysis.

Furthermore, the institute can offer a support infrastructure for single-cell genomics, single-cell proteomics and human organoids, data science and artificial intelligence, clinical research, and sample processing (Jacinto, NIMSB kick-off, October 23, 2023).

3.2. Cross-Functional Capabilities (Group Part)

Besides its internal capabilities, the NIMSB may refer to cross-functional capabilities provided by the MDC and Nova University. Given the close partnership, mutually beneficial synergies may evolve from, e.g., resource sharing. Further, given its renowned status, the MDC can support the research institute in building a favorable reputation. The acknowledgment, in turn, can help the NIMSB increase reliability, which will be useful to obtain additional funding, among other aspects. Furthermore, the NIMSB can benefit from the MDC's unparalleled experience from 31 years in its field (Max Delbrück Center 2023). The institute can seek advice regarding vital decision processes, developmental procedures, and other issues. In addition, the NIMSB is more likely to have access to their expert knowledge, technologies, and samples. In particular, MDC’s wide-ranging research connections can be crucial to the research center, as they involve further potential partners, incl. their expertise and resources. For example, the MDC is part of the ISAAC Foundation, a research network of 10 other institutes (Gorski, interview, October 11, 2023).

Furthermore, the Nova University in Lisbon is an internationally recognized public institution that conducts research and offers multiple study programs (Nova University Lisbon 2023). With its faculties, the university can support the NIMSB in gaining acknowledgment, as well as provide an extensive network, technology, and expertise in various disciplines. Above all, Nova University established a comprehensive innovation ecosystem consisting of

many laboratories and scientific initiatives. The proximity of the university facilitates access to their resources (Jacinto, NIMSB kick-off, October 23, 2023). The university offers a variety of degree programs, s.a. management, biomedical and biochemical engineering, social sciences, medicine, law, tropical medicine, public health, and other subjects. For example, they host a center for entrepreneurship, the Haddad Institute, which focuses on assisting students in turning ideas into start-ups (Nova School of Business and Economics 2023; Nova University Lisbon 2023). In addition, the Nova Medical School (NMS) conducts clinical trials through its Clinical Trials Unit (CTU) and is currently in the process of re-establishing its biobank based on the already available biobanking structures of the Centro de Estudos de Doenças Crónicas (CEDOC) (Calado, interview, October 26, 2023). Moreover, the NMS includes several research initiatives, incl. the Comprehensive Health Research Centre (CHRC), Center for Health Technology and Services Research (CINTESIS), iNOVA4Health, and ToxOmics. These programs include a wide range of interdisciplinary projects in healthcare, biotechnology, and other fields (Nova Medical School 2023). Due to the close partnership between the NIMSB and Nova University, the engagement with students and, hence, identifying potential new talent will be facilitated. Additionally, Nova University provides teaching and training programs as well as funding opportunities (Jacinto, NIMSB kick-off, October 23, 2023).

3.3. External Capabilities (Group Part)

Despite science operating within a global network, certain resources must be in physical proximity. Institutions within Oeiras, Lisbon, and the surrounding area are being examined to identify locally available capabilities, which means that they can be outsourced.

The organizations introduced are intended to provide insight into several potentially valuable external resources in the immediate vicinity.

The research center will be located in a large building near the research institutes Chemical and Biological Technology António Xavier (ITQB), Institute of Experimental and Technological Biology (iBET), National Institute of Agricultural and Veterinary Research (NIAV), and the Gulbenkian Institute of Science (IGC). These organizations are active in various disciplines, s.a. biomolecular medicine, biomedical science, veterinary medicine, systems biology, precision medicine, advanced therapeutics, biotechnology for sustainability, and agriculture. Moreover, the Oeiras campus employs more than 2000 people, incl. doctoral and master's students (Jacinto, NIMSB kick-off, October 23, 2023). Other relevant institutions in the Lisbon area are the Institute of Molecular Medicine of Lisbon (IMM) and the Portuguese Oncology Institute (Instituto Português de Oncologia; IPO). The IMM specializes in biomedical, clinical, translational, and basic research. Additionally, it owns a biobank, incl. an extensive collection of biological samples and clinical data (Dìas, interview, October 12, 2023). The IPO is the largest Portuguese cancer hospital and also offers sample collections from its own biobank (IPO Lisboa 2023).

Additionally, the Catholic University of Lisbon offers various degree programs in medicine, anthropology, biology, chemistry, economics, and other subjects. The university maintains more than 100 scientific facilities and 17 scientific centers. Similarly to Nova University, this can reflect a promising opportunity for relevant talent acquisition. Among others, they offer research in the field of healthcare and biomedicine, collaborating with the Hospital da Luz and conducting research on the Oeiras campus at the IGC (Universidade Católica Portuguesa 2023).

There are hospitals located in the vicinity of the future NIMSB that conduct clinical trials and are specialized in various fields, e.g., the Hospital da Luz and the CUF. The Hospital da Luz belongs to the largest and most modern private hospitals in Portugal, where all major focus areas are represented. Furthermore, they focus on primary care and complicated surgeries (Hospital da Luz 2023). The CUF comprises 24 clinics throughout Portugal dedicated to investigation, development, and training. The clinic also represents many medical disciplines, s.a. cardiology, gynaecology, and oncology (CUF 2023).

The local ecosystem of the NIMSB also includes access to industrial collaboration, hence an opportunity for, e.g., joint research as well as financial returns through licensing agreements. The Tagus Park Oeiras, a hub for technology, communication, healthcare companies, and start-ups, is located close to the future NIMSB site. The innovation park includes 160 companies and 20 start-ups fostering different areas of expertise. The companies focus on designing technologies while working cross-disciplinary (Taguspark 2023). In Lisbon, relevant companies include the healthcare service company Ophiomics, which focuses on applying advanced genomics and bioinformatics technologies. Ophiomics develops personalized solutions for precision medicine and diagnostics in oncology (Ophiomics 2023). There are also many other startups in the region, s.a. Plux, which specializes in creating biomedical solutions for education, research, and healthcare, contributing to an innovative ecosystem (Plux 2023). Additionally, three of the largest pharmaceutical companies, Novartis, Bayer, and Roche, are represented near Lisbon (Bayer 2023; Novartis 2023; Roche 2023).

To summarize, the NIMSB is equipped with valuable resources, s.a. technologies, expertise, and facilities and has established significant initial connections through its collaboration with Nova University and the MDC. Furthermore, it will benefit from its

proximity to a diverse and solid innovation ecosystem. While assessing potential gaps within this ecosystem, it is essential to recognize that the foundation of the NIMSB was driven by specific needs, especially by the absence of specialized technologies in the local region (Jacinto, interview, September 29, 2023). Additionally, the interviews have uncovered a need for focused legal support within the local ecosystem (Crespo, interview, October 10, 2023; Santos, interview, November 14, 2023).

4. Suggested Collaboration Models: Becoming a State-of-the-art Life Science Institute

The previous analysis has demonstrated collaborations as an important tool to meet the NIMSB's identified objectives. The previously illustrated needs and resources of the NIMSB serve as a basis for the following discussion of potential collaboration models, incl. their benefits and challenges. Actual examples of potential partners support the individual types of collaborations. However, it must be considered that these examples are no exclusive options, as alternatives exist. The effective implementation of the collaborations requires a more comprehensive analysis.

4.1. Collaborative Research Projects Suggested Partnerships for Ensured Mutual Resource Sharing

Collaborative research projects are crucial to address needs, s.a. missing resources, education, industry engagement, and economic and social value creation. Collaborative research is designed to productively achieve common objectives, focusing on a collective and

interactive approach (Wray 2002, 14). Such collaborations also allow for shared resources. This is particularly vital in the initial phase of establishing the NIMSB, where significant investments are required to cover the high costs of infrastructure, specialized equipment, recruitment, and other aspects (Mohrman and Wagner 2008, 23). Similarly, the NIMSB can share its available resources with potential partners, s.a. strategically-well-located facilities, laboratories, specialized technologies, expertise, and specific research methods (Jacinto, NIMSB kick-off, October 23, 2023).

4.1.1. Potential Partnerships

Collaborative research projects can be initiated with (1) other research centers, (2) universities, (3) pharmaceutical companies, (4) investing organizations, s.a. venture capital firms and business angles, (5) hospitals, (6) governmental entities, and (7) technology companies.

(1) Other research institutes can serve as valuable partners in achieving common goals. These partners can be specialized in intersecting as well as different research fields to generate complementary synergies (Rycroft‐Malone et al. 2015, 4). Due to their proximity and similar focus on medical research, the NIMSB should consider partnerships with the IGC, IBET, ITQB, IMM, Nova University's and the Católica University's research facilities. With its substantial size and reach, the IGC may have superior capabilities to support the NIMSB (Gulbenkian Science 2023). Institutes like the IBET or ITQB might be interested in expanding and co-locating within the NIMSB's facilities. Partnering with the IMM could be highly beneficial due to their extensive and valuable collection of samples, which is crucial for ensuring sample diversity (Gorski, interview, October 11, 2023). On an international level, the Max

Planck Institute for Informatics in Germany could be a valuable partner for the NIMSB, offering expertise in computer science and machine learning to enhance AI-related research (Max-Planck-Gesellschaft 2023). Similarly, acknowledged and innovative life-science organizations, s.a. the Francis Crick Institute in London, may also be considered as potential partners (The Francis Crick Institute 2023). Partnering with organizations like the European Bioinformatic Institute (EBI), located on the Wellcome Genome Campus near Cambridge, could add value through support in analyzing large data sets for multi-omics (European Bioinformatics Institute 2023). Besides leveraging external resources, the NIMSB can similarly act as a valuable resource provider. Particularly, in the starting phase, it can be beneficial to provide added value and thus foster new partnership opportunities. The institute's specialized technologies, along with the MDC's expertise and experience, are particularly advantageous for local research institutions like the IMM, which has expressed interest (Dìas, interview, October 12, 2023; Gorski, interview, October 11, 2023).

(2) Universities can be collaborative research partners. For example, the NIMSB can collaborate with various universities' faculties of entrepreneurship and management, s.a. the Nova SBE’s Haddad Institute for Entrepreneurship. Available resources and expertise could be pooled to turn scientific findings into marketable solutions and potentially generate start-ups and spinouts. Furthermore, cooperating with acknowledged institutions makes it more likely to e.g., receive funding for the projects (Mohrman and Wagner 2008, 17). Other useful and innovative research entities within Nova University's network include ToxOmics and iNOVA4Health, which connect research partners and thus facilitate collaborative research (Nova University Lisbon 2023). Given its unique sample collection and proximity, NMS stands out as a

potential partner for specimen collection, among other things. However, a thorough needs assessment must be conducted to address the challenge of duplicating samples in the same area (Calado, interview, October 26, 2023). Moreover, collaboration with diverse national and international universities that offer specialized skills and other capabilities relevant to the NIMSB should be explored. For instance, the University College Dublin (UCD) and the Massachusetts Institute of Technology (MIT), which are also open to partnerships with smaller expert research institutes, could be evaluated as potential collaborators (O'Beirne, interview, November 16, 2023; Roberts, interview, December 4, 2023).

(3) Pharmaceutical companies can support the development of medical solutions and start-ups. Additionally, collaborations in these areas are advantageous to accelerate drug discovery. The NIMSB can provide technologies and hence receive support in the form of financial means and industry expertise (Gomes, interview, October 27, 2023; Kennedy, interview, October 13, 2023). Additionally, in this context hospitals serve as essential potential collaborators, performing the clinical trials needed to test the drugs on patients (Barros, interview, October 31, 2023). Partners may involve pharmaceutical industry leaders, s.a. Roche, Bayer, and Novartis, along with other relevant players in the field. Nevertheless, the NIMSB may face various obstacles in coping with major industry players. Such challenges include the attraction of globally renowned companies, ensuring regular communication, and addressing frequent changes in the healthcare system (Benz, interview, October 13, 2023).

(4) Partnering with investing organizations, s.a. venture capital firms and business angles, is advised to secure strategic and financial support for the creation of life-science start-ups (Faster Capital 2023). Once spinouts are generated, leveraging an ecosystem

of life science investors will be of huge value for both the founders and the NIMSB. More detailed information on the topic of funding start-ups and cooperation with companies can be found in section D.

(5) Hospital collaborations offer clinical resources to address specific research challenges collectively. In turn, the NIMSB can provide specialized expertise and technologies to advance translational medicine effectively (Barros, interview, October 31, 2023). The research institute should explore collaborations with well-established and nearby healthcare facilities, s.a. CUF, Hospital da Luz, Hospital Fernando Fonseca, and other hospitals (Hospital Professor Doutor Fernando Fonseca 2023). The partner selection depends on the specific requirements and the potential for complementarity of the stakeholders. Additionally, for research in rare diseases, international specialized hospitals like Gustave Roussy in France or the Charité could represent valuable partners (Benz, interview, October 13, 2023; Gustave Roussy 2023).

(6) The NIMSB should closely engage with governmental entities, supported by university faculties and research centers, initiating research projects tailored to the community's needs, yielding insights for public health recommendations. An example would be the collaboration of the Oeiras municipalities, the Nova Medical School, and the Faculty of Sports in Lisboa to drive research on community health in relation to sports. These partnerships could also be used to jointly provide health education campaigns and promote funding and engagement in clinical trials (Faculdade de Motricidade Humana 2023; interview, Brigadeiro, October 18, 2023).

(7) Collaborations with specialized technology firms will allow for combined expertise and resources and may support the development of innovative healthcare solutions (Gomes, interview, October 27, 2023). Technology start-ups from Tagus Park and

other IT companies, s.a. Ophiomics and Sword, could be considered as partners (Sword 2023). However, based on available resources and common goals, a diverse range of national and international companies should be approached.

Generally, the complementary expertise and regular discourse between these entities will foster creativity and innovation (Dusdal and Powell 2021, 34). Furthermore, the division of responsibilities may enhance efficiency.

4.2. Joint Training and Trend Scouting

Collaborative training and trend scouting programs offer opportunities to meet and tackle the aforementioned needs for human resources, expertise, funding, education, marketing, and communication. In addition, the partnerships contribute to economic and social value creation. Institutions join forces to empower young talents and professionals within healthcare through courses, degree programs, and other educational initiatives (Barros, interview, October 31, 2023; National Center for Education Research 2023).

4.2.1. Potential Partnerships

Joint training and trend-scouting collaborations can be considered with six different types of partners: (1) Research centers, (2) universities, (3) hospitals, (4) technology companies, (5) governmental entities, and (6) a coaching company.

(1) Collaborating with other research centers will be crucial to jointly provide training and internships within their respective areas of expertise. Interactive educational programs, s.a. workshops, seminars, and webinars, can be offered to encourage the new generation of, e.g., scientists (Michalska-Falkowska, interview, October 17, 2023). In addition, the institutes could offer rotational internships, giving a perspective on

different career options and guiding people regarding sound career choices (interview, Brigadeiro, October 18, 2023). During the training sessions, it is suggested that talents are evaluated and searched collaboratively among the participants. Regarding research institutes, a partnership with the nearby ITQB could be advantageous. For example, specialized courses combining biotechnology and molecular medicine can be developed, leading to a more comprehensive and interdisciplinary educational offering. Another potential partner could be, for instance, an institution, s.a. the PenState Social Science Research Institute. Jointly, the stakeholders can create courses addressing a wide range of topics, from healthcare system challenges to broader social issues, leveraging their expertise in these fields (PenState Social Science Research Institute 2023).

(2) In addition, researchers can be incentivized by teaching certain subjects at universities and simultaneously contribute to the promotion of the research institute (Barros, interview, October 31, 2023). Moreover, mentoring programs for Master's and PhD students, as well as access to laboratories, can be provided by the NIMSB (Dìas, interview, October 12, 2023). Collaborations with innovative research universities like those of Nova University and Católica University, as well as with international entities, should be considered based on mutual interests, capabilities, and willingness to engage.

(3) The NIMSB could provide specialized data analysis training to healthcare professionals in hospitals (Leite, interview, October 18, 2023). The research institute might consider offering a range of training programs as paid services. Management students from, e.g., the Nova School of Business and Economics, could play a crucial role in enhancing NIMSB's offerings by assisting in the design and organization of

tailored courses (Nova School of Business and Economics 2023). Collaboration with CUF, which has expressed interest in NIMSB's technology, could be explored. This partnership might encompass joint research projects and providing training to familiarize CUF's clinical staff with NIMSB technologies, thereby facilitating multi-level cooperation and strengthening the relationship. However, given that CUF already engages in training initiatives for external organizations, it is vital to ensure a mutual interest in such collaborations (Barros, interview, October 31, 2023).

(4) Given the challenge of finding technology experts within research, launching joint training programs with technology companies would be beneficial (Dìas, interview, October 12, 2023). The IT professionals could receive training in research-specific topics, while research institutes could strengthen technological areas. Potential partnerships include large-scale collaboration with OutSystems, a leading IT company in Portugal, as well as other stakeholders in Tagus Park (Outsystems 2023).

(5) NIMSB and government agencies could collaboratively organize specialized degree programs and training initiatives focused on healthcare and medical systems biology. Partnering with governmental entities is crucial to receiving financial support, e.g., in the form of grants and subsidies for educational initiatives (Brigadeiro, interview, October 18, 2023).

(6) Additionally, the NIMSB could collaborate with communication trainers to support its researchers in advancing their presentation skills, enabling them to effectively convey their research findings and the institute's mission to the broader public (Leal, interview, October 19, 2023).

Joint training initiatives are essential for the effective development of human capital, enriching the ecosystem, promoting networking, and improving the overall image.

4.3. Strategic Marketing Partnerships

To effectively communicate the NIMSB´s capabilities, a strategic marketing partnership can significantly boost its visibility within the scientific community and the broader public. Effective marketing strategies can help establish the NIMSB as a leading institution in medical systems biology, attracting attention from potential research partners, investors, and top talents (Gomes, interview, October 27, 2023). Thus, identified needs of resources, education, marketing and communication, industry engagement, and social and economic value creation can be tackled.

4.3.1. Potential Partnerships

Strategic marketing partnerships can be established with (1) Research institutes, (2) municipalities, (3) universities, and (4) pharmaceutical companies.

Marketing activities may encompass many areas, s.a., utilizing online platforms for outreach, including website optimization, social media engagement, email marketing, and content marketing. Potential partners may include specialized science communication agencies and digital marketing firms (Sablon, interview, October 19, 2023). However, interviews have shown that attending and organizing scientific events may be the most powerful source of capability communication. Thus, hosting recurring research events in Oeiras would be beneficial (Leal, interview, October 19, 2023). The venues are, among others, intended to serve as a platform for introducing the NIMSB to the scientific community, attracting potential research project-, clinical-, or industry partners, and concurrently creating value for the ecosystem. Ideally, engagement in an innovative, pleasant, and inspiring environment is fostered. Furthermore, the importance of effective marketing was noted as being essential for

fostering efficient collaboration in research (Gomes, interview, October 27, 2023; Leal, interview, October 19, 2023). Portuguese institutions' limited participation in international events underlines the importance of representing the country in research (Gomes, interview, October 27, 2023).

(1) Research institutes, (2) municipalities, and (3) universities should unify to support the organization of research events. The partners can contribute expertise, organizational skills, facilities, financial support, reputation, and relevant connections (Crespo, interview, October 10, 2023). The Nova University, due to its proximity and established network, represents a compelling partnership option. The same applies to the local research institutes, s.a IGC, ITQB, and iBET. Moreover, to increase visibility and impact, it is essential to target a diverse range of national and international partners, e.g., the University of Lisbon (Sablon, interview, October 19, 2023). Representatives of large institutions like the Research University of Ghent in Belgium can be considered as potential guest lecturers or co-hosts (Ghent University 2023; Universidade de Lisboa 2023). Furthermore, the NIMSB could organize panel discussions or other types of presentations with the globally recognized Institute for Systems Biology in Seattle (ISB), known for its pioneering work in molecular systems biology (ISB 2023). Collaborating with renowned organizations can help attract relevant partners due to their credibility and influence. However, it is difficult to engage established organizations for an unknown event as they might want to understand its value and potential impact before committing.

Moreover, industry players like (4) pharmaceutical companies should be specifically targeted at the events as this represents a mutually beneficial source of exchange. For the industry, attending such events is a convenient way to stay on top of current research trends.

For the NIMSB, this may serve as the ideal platform for showcasing technologies that are attractive for licensing and thus ensure revenue return (Leal, interview, October 19, 2023).

It is advisable that the events encompass engaging discussions, live podcasts, and interactive workshops. Engaging compelling speakers and personalities is crucial to make the venues captivating and unique. However, initially, attracting high-profile individuals may be challenging. The strategic location of events in Oeiras Valley, near the technology park, is expected to attract diverse professionals and firms (e.g., legal firms), enhancing the NIMSB's popularity in the scientific sector (Leal, interview, October 19, 2023). This will establish the research center as a key entity for the municipalities, aligning with their interests in visibility and generating economic value (Brigadeiro, interview, October 18, 2023).

4.4. Other Types of Collaborations

Beyond the collaborations already outlined, the NIMSB should engage in additional partnerships. These include crucial alliances with (1) legal advisory firms and (2) international institutions. Providing legal frameworks is crucial to facilitate partnerships and make NIMSB more attractive for collaborations. Furthermore, it is essential to focus on international partners to broaden opportunities, increase impact, and thus expand the network. Potential collaboration with legal advisory companies and international organizations are outlined in detail in Appendix 7.

5. Practical Recommendations (Group Part)

Drawing upon the conclusions gained from expert interviews and literature review, the newly established NIMSB should prioritize certain recommendations. The proposal

encompasses actionable steps and theoretical considerations, laying the foundation for achieving the objective mentioned above.

The development of groundbreaking life science is based on an extensive global network, which implies that research institutes cannot function in isolation. Diverse collaborations with acknowledged local, national, and international organizations are crucial to foster long-term success. Identified relevant requirements, s.a. improving marketing and communication, developing a skilled workforce, securing financial support, and establishing regulatory frameworks, should be addressed as top priorities by the NIMSB. The following partnership models, leading to mutually beneficial synergies, should be applied to tackle the critical needs:

(1) The NIMSB should prioritize the ***"Collaborative Research Project Model"***, focusing on ***sharing resources*** to enhance a strong positioning within the ecosystem and facilitate collaboration. The strategic approach aims to provide and leverage capabilities to receive support from potential partners. It is recommended to provide internally available and easily accessible resources, s.a. specialized technologies and expertise that have been identified as lacking within the ecosystem. Sharing resources simultaneously supports the NIMSB in developing critical resources, especially in the initial phase when significant investment is required.

(2) In the early stages, it is crucial to engage proactively in ***"Strategic Marketing Partnerships"*** through, e.g., events to achieve an impactful introduction of the NIMSB. Concurrently, these events aim to collaboratively promote the combined strengths of all partners, effectively presenting Oeiras Valley as a unified entity. The NIMSB has to become a place for fostering exchange and TT in an innovative and inspiring research environment. This setting also enables the NIMSB to advocate for

its specific needs, s.a. funding, legal advice, staffing, and training programs. The local connections, initially strengthened by sharing resources and the reputation of Nova University and MDC, facilitate the attraction of national and international partners. The participants of the venue will provide new collaboration opportunities, incl. various benefits, eventually covering the NIMSB´s focal needs.

(3) ***Collaborations with hospitals or clinics, biobanks, and pharmaceutical companies will be fundamental*** for effectively addressing the diverse critical needs of the NIMSB. Different collaboration models in these fields should be implemented, supporting the research institute in building essential resources and adding value to the ecosystem. For instance, engaging with hospitals, clinics, and biobanks provides access to core research assets, s.a. human-biological samples, clinical data, and expertise. Furthermore, industry partnerships are crucial for technology transfer, generating sustained income, and eventually enhancing societal influence. While the topics of biobanking, clinical trials, and industry collaborations have been briefly discussed, their importance and impact on the overall concept of the NIMSB and its core objectives have yet to be analyzed.

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Section B: Opportunities and Barriers of Biobanking (Group Part)

The opening chapter of this thesis provides an outline of the main objectives and vision of the NIMSB, emphasizing certain areas that have not yet been fully defined. Among

the focus areas is the field of biobanking or the process of acquiring samples for the NIMSB. The previous chapter on local collaborations already stressed the importance of establishing a local collaborative network, incl. stakeholders within the biobanking network. The present chapter raises significant questions regarding the opportunities and barriers that the NIMSB encounters in utilizing biobanking to advance research and its recognition in the wider scientific community. Thus, the following investigation aims to provide insights into the practice and feasibility of integrating biobanking within the NIMSB's activities. This includes a fundamental examination of biobanking, encompassing its integral elements and inherent value proposition. Subsequently, the benefits and challenges associated with different approaches to collecting and sharing samples, specifically in relation to the NIMSB, are comprehensively analyzed. Finally, strategical and practical recommendations are provided for the NIMSB in implementing biobanking or sample collection procedures. These recommendations aim at creating mutual benefits for the NIMSB and the broader research community.

1. Value Creation and Impact Generation Through Biobanks (Group Part)

Biobanks have a crucial role in advancing medical science, (systems) biology, and healthcare delivery by serving as repositories for biological specimens (Kinkorová and Topolčan, 2020, 333-341). Biological repositories, as emphasized by Pelisek et al. (2019), are carefully constructed to enhance our understanding of various diseases and are vital for the

progress of novel and pioneering treatment strategies. The extensive collection of patient samples can help in promoting personalized or precision medicine, incl. prevention, diagnosis, treatment, and personalized monitoring (Kinkorová & Topolčan, 2020). Biobanks play a crucial role in coordinating and mediating between medical institutions (i.e., clinics and hospitals), research institutions, and pharmaceutical companies (Abdulghani, interview, November 22, 2023; Dìas, interview, October 12, 2023; Kennedy, interview, October 13, 2023; Penney, interview, November 27, 2023). When executed properly, Biobanks can effectively fulfill their primary objective of generating impact for each of these stakeholder groups. This will be further elaborated in the subsequent discussion (Castillo, interview, November 22, 2023; Divers, interview, November 15, 2023).

1.1. The Medical Perspective (Group Part)

From a medical standpoint, biobanks support the advancement and validation of novel diagnostic techniques, empower individualized care, and strengthen the surveillance and management of chronic and infectious illnesses through organized and processed sample provision. Thereby, patients benefit from precise diagnoses, individualized treatment strategies, and perhaps earlier intervention, all of which can significantly enhance their prognoses and long-term health. Furthermore, the availability of a diverse collection of biological specimens facilitates our understanding of disease progression and response to therapy. This significantly supports healthcare professionals in generating accurate medical judgments (Hewitt, Watson, and Dhir, 2014, 4-9). The knowledge transfer and technological innovations that occur as a result contribute to the overall improvement of patient care and medical procedures. Biobanks may also add value in clinical trials conducted by investigators,

pharmaceutical companies, or clinical research organizations. During clinical trials patient biological samples and their associated data are collected and may be integrated into biobanks for future and retrospective research (see definition of retrospective research in Appendix 2) (European Commission 2012; Mouta, interview, November 3, 2023). This interaction between biobanks and institutions conducting clinical trials is further elaborated in section C.

1.2. The Scientific Perspective (Group Part)

For biomedical and scientific research, researchers and research institutes utilize specimens to understand complex diseases at the molecular level (Dìas, interview, October 12, 2023; Gorski, interview, October 11, 2023; Kaunisto, interview, November 10, 2023; Michalska-Falkowska, interview, October 17, 2023). Biological repositories guarantee the quality and integrity of research specimens by providing a structured collection and preservation of specimens. This is essential in assuring more accurate dependability and replicability of research findings (Stege, interview, December 12, 2023). Ashley Sanders, Group Leader at the BIMSB, specifically pointed out the significance of biobanks in facilitating the transfer of research findings on single cells from one patient to multiple others by analyzing organized and processed samples (Sanders, interview, December 13, 2023). In addition, biobanks facilitate cooperation among academics and research institutions and across several other disciplines, forstering the scientific discourse and accelerating the rate of advancement in fields, s.a. genomics, proteomics, and epidemiology (Watson, Barnes, and Datta 2019). They serve as intermediaries between clinical research units and research groups conducting specialized research initiatives by storing specimens in an organized way for prospective research as was emphasized by Sanders during her lecture at the NIMSB kickoff.

1.3. The Commercial Perspective (Group Part)

Biobanks serve as a gateway between academic and scientific research, and industry, facilitating the rapid transformation of research discoveries into marketable assets and services. For instance, pharmaceutical organizations employ biobank resources to expedite drug research and development, hence decreasing the time and expenses associated with such procedures. In addition, biobanks offer useful data that can be utilized to discover new therapeutic targets or categorize people for clinical trials, thereby improving the efficacy of drug development processes (Zika et al. 2011, 96-103). This was also pointed out by the Vice President of Bayer US, as pharmaceutical companies like Bayer strongly benefit from biobank collaboration at the beginning of the drug development process to identify targets and their prevalence and later on for support in sample acquisition (Penney, interview, November 27, 2023). Similarly, when engaging in clinical trials, pharmaceutical companies may distribute specimens to biobanks for future research purposes after their own analysis objective has been met (Kennedy, interview, October 13, 2023). There are four key factors that pharmaceutical companies may look for in biobank partners, namely (1) sample availability (i.e., the required type of sample), (2) hospital relationship, (3) strong documentation around consent enabling sample and data sharing with industry, and (4) a strong database and infrastructure which ensure high sample and data quality. Besides, start-ups can benefit from biobanks to facilitate innovation and advance the development of novel diagnostics, treatments, and medical technology. Similarly, as with pharma companies, biobanks enable smaller businesses easy access to top-notch biological samples and related data, fostering an environment where they can spur innovation, create economic worth, and ultimately enhance global health outcomes.

1.3.1. Challenges of a Centralized Biobanking Model (Group Part)

The establishment of a biobank in the NIMSB also presents notable obstacles that must be taken into account. First, it is associated with ***substantial expenses.*** According to the Head of Biobanking at the Victorian Cancer Biobank in Australia, the majority of biobanks will only be able to cover a mere 20 percent of their expenses. The costs arise from various factors, incl. (1) physical facilities, e.g., lease, electricity, and water; (2) equipment for specimen processing and storage, incl. freezers, liquid handling machinery, and cabinets; (3) staffing and administration, (4) transportation and logistics, incl. samples collection and transportation, (5) IT and data management, incl. software and hardware for data storage and analysis, and from (6) marketing and outreach activities for donor community engagement and education (Campbell et al. 2018; Calado, interview, October 26, 2023; Kaunisto, interview, November 10, 2023; Ng, interview, October 25, 2023; Stege, interview, December 12, 2023). Since biobanks are bound to keep a non-profitable status mandated by law, it is important to implement a solid cost-recovery model (Abdulghani, interview, November 22, 2023; Dìas, interview, October 12, 2023; Stege, interview, December 12, 2023). This must be considered for any cost and price specifications of to be shared sample and data collections. Additionally, the NIMSB should try to build up a strong industry collaboration network and benefit from medical treatment patent-, licences-, and partnership agreement profits. These profits are frequently reinvested in biobanks, positively influencing their long-term sustainability and ongoing significance in biomedical research and clinical trials (Dìas, interview, October 12, 2023, Gomes, interview, October 27, 2023).

Secondly, building up a biobank is a ***highly complex and lengthy process***, therefore requiring a stringent strategic and operational guideline with the according expertise, as was also highlighted in section A. The entire process of defining and implementing consecutive structures and operations should not be underestimated. For example, a challenging aspect refers to identifying the specific requirements of sample requests from researchers in order to be able to provide the appropriate and necessary samples. This is subsequently followed by an extensive and time-consuming sample collection process (Ng, interview, October 25, 2023; Stege, interview, December 12, 2023). It will be essential for the NIMSB to clearly outline its primary areas of research and to define the corresponding sample types that can support progress in these research areas. For example, even while wanting to collect specimens of a more common cancer type like breast cancer, it is necessary to accurately determine the precise type and stage of the cancer. If researchers do not have access to this specific sample collection, they must be willing to utilize alternative resources (Ng, interview, October 25, 2023; Kaunisto, interview, November 10, 2023). The limited sample storage capacity of biobanks aggravates this challenge. Additionally, due to the NIMSB's aim to analyze omics data, which involves a highly technical and complicated process, it will be specifically important to implement a solid IT infrastructure (see definition of omics data in Appendix 2) (Abdulghani, interview, November 22, 2023, Stege, interview, December 12, 2023).

Furthermore, as explicitly discussed in section A, the NIMSB has not yet formed any sort of partnership with a nearby hospital. However, such a ***partnership is highly crucial*** and should be established from the outset in order to ensure the consistent acquisition of samples (Abdulghani, interview, November 22, 2023). As emphasized by the Head of Biobanking Development at BBMRI-ERIC, it is much more convenient to partner with local hospitals (i.e., in Oeiras) in terms of transportation and logistics. Hospital da Luz has previously

partnered with several biobanks in Lisbon and is now initiating a larger collaboration with the clinical academic center of the Catholic University of Portugal (Leite, interview, October 18, 2023). Section A also provides a deeper outlook into potential collaboration models with hospitals in the Lisbon area.

A final obstacle arises from the ***competitive biobanking landscape*** in the Lisbon region (Abdulghani, interview, November 22, 2023). This landscape already includes well-established biobanks like the IMM Biobank or the Champlaumidaud Foundational Biobank, as well as the formerly called CEDOC biobank of the Nova Medical School. The previous analysis of sample collections in Portugal has shown that the diversity of sample collection in the Lisbon area is currently rather well-balanced. However, the NIMSB should be cautious of potential overlaps as it establishes itself as a biobanking organization in it this environment. During the conversation with the Biobanco IMM and the Nova Medical School Biobank, both parties expressed genuine interest in collaborations with the NIMSB and emphasized the importance of maintaining distinct areas of focus for sample collecting in order to prevent any potential overlap (Leite, interview, October 18, 2023; Dìas, interview, October 12, 2023). With a centralized biobank, it will be crucial for the NIMSB to set itself apart from other biobanks on a national and international level through specialized samples and high quality data collection (Abdulghani, interview, November 22, 2023).

2. Strategic Insights and Recommendations for Biobanking for the NIMSB (Group Part)

The previous analysis and exploration of interview insights, along with the literature review, do not suggest a one-sided solution for the integration of biobanking at the NIMSB. Since the samples are definitely required for single-cell multi-omics analysis, it is out of the question for the NIMSB to collect samples. However, the way in which this happens follows a complex and strategically crucial decision-making process and should be considered most carefully. Taking into account both the benefits and challenges of the previously analyzed integration models and considering the complexity of establishing a biobank, **it is recommended that the NIMSB adopts a combination of the centralized and external sample acquisition model**. This would mean that the NIMSB develops additional biobanking facilities at the Oeiras campus on a smaller scale (incl. storage and processing facilities) as an extension of an already established biobank of another institution. An illustration of this approach can be found in Figure 6 in Appendix 14. In this case, the NIMSB's biobank would operate as a joint entity alongside the biobank of the other institute, hospital, or university, e.g., the Biobanco IMM, the Biobank of the Nova Medical School, or the Portuguese Oncology Institute (IPO). To comprehend the final recommendation, it is useful to recollect the key components of biobanking. These four points were also inferred from the interview findings and the definition and purpose of biobanking: (1) structured and ethical sample collection and processing (i.e., quality control, ELSI compliance, and robust IT infrastructure), (2) strong collaborations for sample acquisition, (3) sustainability and funding, and (4) impact generation. These should be considered in any decision-making process.

Adopting the described model can have a positive reciprocal effect on all four components, which will be further elaborated in the following.

2.1. Structured and Ethical Sample Management Through Shared Resources (Group Part)

A combined model will ensure a more structured and ethically-correct sample collection and management from the beginning of the project due to the opportunity to leverage already established structures and organizations provided by another biobank or institution, as well as the accumulated industry knowledge and expertise around biobanking. This includes quality control, compliance with ELSI, and the IT and data management infrastructure. Establishing organized processes and structures to ensure high-quality samples is highly complex and requires significant effort. Like many other institutions, the Nova Medical School dedicated a minimum of three years to establishing the present state of its biobank by conducting visits and engaging in discussions with experts from other biobanks in Portugal and Europe (Calado, interview, October 26, 2023). The NIMSB can greatly benefit from this unique expertise and the opportunity of knowledge transfer. Furthermore, leveraging this knowledge in understanding the multifaceted aspects of ELSI and putting them into practice in the correct way will offer another great opportunity to the NIMSB when engaging in the collection of samples. It will not only support the NIMSB in gaining the public's and patient's trust but also in ensuring a renowned positioning within the research and life science industry community, which is also crucial for funding. Although there are many available resources and best practices from networks, s.a. the BBMRI-ERIC, the ability to leverage insights from a partnering already experienced institution or even benefit from their

certifications can make a substantial difference (BBMRI-ERIC 2023). It also facilitates better understanding of local needs and requirements. Adopting a combined model is additionally advantageous in the development and enhancement of a robust IT and data management infrastructure. The NIMSB biobank may be able to benefit from shared and existing resources in terms of IT management systems and already built-up infrastructure from the collaborating biobank.

2.2. Stronger Collaboration and Better Sample Acquisition (Group Part)

In a combined model, the NIMSB will benefit from **already established partnerships**, not only with pharmaceutical companies but also with renowned hospitals in the wider Lisbon area, s.a. Hospital da Luz, CUF, or the Portuguese Oncology Institute (IPO) (i.e. the largest cancer hospital in Portugal). Additionally, such a combined paradigm would significantly increase the amount and **diversity of sample sets** and simplify the sharing processes of those samples and their associated data between two joint entities. For example, the NIMSB and Nova Medical School's biobank could optimize their resources by strategically coordinating their sample collections. Redundancies can be avoided when each biobank focuses on distinct types of samples, enabling a synergy effect where both benefit from the unique and complementary nature of each other's repositories. This collaboration would enhance the efficiency of both biobanks and additionally expand the scope and depth of their research possibilities.

2.3. Improving Sustainability and Funding (Group Part)

Although the combined model would still require substantial financial investment, expenses could be reduced through **shared resources** for marketing, IT management, staffing (e.g., quality and legal assurance), and other biobanking elements. As mentioned, a detailed and reliable cost-recovery model should be created for this purpose (Abdulghani, interview, November 22, 2023). Given the substantial rise in energy and electricity costs, these concerns will become increasingly relevant (Abdulghani, interview, November 22, 2023). This can be achieved, for instance, by fostering **strong engagement with the pharmaceutical sector and grant givers** to generate revenue for re-investment in Research & Development by filing licenses and patent applications and gaining revenue through partnership agreements (Michalska-Falkowska, interview, October 17, 2023). Furthermore, teaming up can improve opportunities for funding as mentioned in chapter 6.3 .

2.4. Ensuring Impact Generation (Group Part)

As was emphasized by the Retired Director of the KI Biobank and derived form the purpose of biobanking, generating and measuring quantifiable impact as a biobank is crucial and should not be overlooked. Useful KPIs may be, for example, the number of supported projects through sample distribution. In the recommended model, this impact might be even stronger than in a centralized biobank model only due to several reasons. The **reduced time and effort** regarding all administrative and organizational tasks that a combined model entails should rather be allocated to **advancing processing and analysis** of the specimen collections. This has substantial impact on the research projects quality analyses and outcomes. Advanced

analyses technologies, s.a. single-cell multi-omics or AI, and their potential for improved patient health outcomes will be further elaborated in section C.

3. Conclusion (Group Part)

In conclusion, while biobanking is a highly complex and costly matter, its potential to provide value both to the NIMSB's research progress as well as to the wider research community both locally and internationally is substantial. The analysis has outlined that the benefits clearly outweigh the challenges in a combined model for biobanking. Considering the unique positioning and available network of the NIMSB, it is strongly advised for the NIMSB to collaborate closely with this network and leverage existing infrastructures, expertise, sample collections, and partnerships when engaging in biobanking and building up internal storage and processing facilities. When executed adequately, this step can represent an important milestone in the NIMSB's objectives to develop and position itself as a world-class research program in Medical Systems and advance human health outcomes.

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Section C: A Blueprint for Clinical Trial Contribution (Group Part)

Recognizing the significance of collaborations and biobanking for accelerating research and extending the NIMSB´s reach within the previous sections, the present research shifts focus to exploring the institute´s potential contributions to the clinical trials sector. The critical role of clinical trials in healthcare, coupled with the current demand for rapid

technological innovation (Hardman et al. 2023, 1-11), highlights the importance of the NIMSB in exploring these opportunities. This analysis aims to uncover how the NIMSB can utilize its capabilities to enhance its scientific and societal impact significantly, underlining its relevance in health sciences and its prominence in the academic community. The following section will provide a comprehensive overview of clinical trials, starting with their definition and importance in clinical research. This will be followed by an exploration of the clinical trials market, identifying key trends and challenges pertinent to the NIMSB. The analysis will then delve into potential contribution opportunities for the NIMSB, ensuring alignment with market needs identified earlier. Finally, the strategic benefits of these potential contributions will be examined, leading to tailored recommendations for effective implementation. This approach aims to map out a clear pathway for the NIMSB´s meaningful engagement in clinical trials, enhancing its role in advancing healthcare research.

1.1. Exploring Additional Potential Contributions of the NIMSB to Clinical Trials (Group Part)

In addition to its crucial contributions to translational research and patient stratification, the NIMSB can extend its influence to several other vital areas and challenges of clinical trials. This broader engagement enables the NIMSB to effectively utilize its expertise and resources to improve various facets of the clinical trial process.

1.1.1. Training and Educational Initiatives (Group Part)

Discussions with Barros, the Director of CUF Academic Center, Leite, the Executive Director of Hospital da Luz and Calado, the Vice-Dean for Research at NOVA Medical School, have highlighted the critical need for enhanced skills in AI and single-cell multi-omics within clinical trials. The NIMSB can meet this demand by offering specialized training programs tailored for medical staff, particularly in hospitals keen on adopting these innovations. Such initiatives would align with the NIMSB's objectives to train a new generation of researchers and medical doctors (Jacinto, interview, September 29, 2023). By addressing this knowledge gap, the NIMSB can empower healthcare professionals with the necessary skills to effectively utilize advanced biomedical technologies and data analysis techniques, ultimately enhancing the application of these technologies in clinical settings (Barros, interview, October 31, 2023; Leite, interview, October 18, 2023; Calado, interview, October 26, 2023). In addition, the NIMSB can contribute through guest lectures and joint workshops focusing on the latest clinical trial trends and innovations. These efforts foster continuous learning and knowledge exchange among healthcare professionals, benefiting everyone involved in clinical trials and patients.

1.1.2. Management of Clinical Trial and Data (Group Part)

The NIMSB's expertise in AI and complex data analysis can significantly improve the management and analysis of clinical trial data by increasing the depth and quality of research. By using AI to interpret datasets from single-cell multi-omics derived from patient samples, the NIMSB can significantly improve data quality and optimize the efficiency of the research process itself (Jacinto, interview, September 29, 2023; Leite, interview, October 18, 2023). In

addition, the NIMSB's potential to provide advanced AI-powered management systems could revolutionize clinical trial workflows and increase efficiency from patient recruitment to data analysis. By using these systems, institutions, s.a. CUF, could experience a paradigm shift in the coordination of clinical trials, leading to a more seamless and integrated conduct of research activities (Gouveia, interview, November 14, 2023). The broader application of the NIMSB's data management and process optimization expertise could improve clinical trial operations, potentially setting new benchmarks for efficiency and reliability in clinical trials.

1.1.3. Patient-Centric Approaches (Group Part)

The NIMSB's adoption of patient-centered approaches promises significant improvements in clinical trial participation and participant diversity. Community outreach programs that communicate the information and relevance of clinical trials could effectively increase trial participation and retention, demonstrate the NIMSB's commitment to advancing medical research, and underscore the importance of clinical trials to the healthcare system. In addition, the NIMSB can increase diversity in patient recruitment through its connections to diverse populations in Portuguese-speaking countries in Africa and South America. This strategy aligns with the globalization trend in clinical trials. It ensures broader applicability and reliability of medical treatments across different demographics, improving the overall impact for stakeholders and patients worldwide.

1.1.4. Science-Based Venture Building (Group Part)

The NIMSB is set to transform clinical trials by incubating startups focused on technologies like patient safety monitoring devices. Emphasizing the development of

AI-driven diagnostic tools and data analysis platforms, this initiative addresses the needs of DCT, RWD, and RWE (Appendix 18, Appendix 17).

2. NIMSB´s Strategic Benefits for Clinical Trial Support (Group Part)

The strategic involvement of the NIMSB in clinical trials, as outlined in Chapter 3.0., presents a spectrum of advantages that align with the institute's core objectives. These benefits extend beyond commercial success, encompassing a profound impact on medical research and the enhancement of patient outcomes.

2.1. Collaboration and Resource Access (Group Part)

Given that the NIMSB does not conduct clinical trials itself, its contributions to this field are realized through strategic collaborations. These partnerships are instrumental in providing the NIMSB with significant resource access. Collaborating with pharmaceutical companies, s.a. Bayer, offers the NIMSB access to extensive compound libraries and sample collections, exceeding the typical scope of academic research and valuable pharmaceutical expertise (Gorski, interview, October 11, 2023). Integrating the NIMSB's advanced technologies with the extensive resources of pharmaceutical companies enriches the NIMSB's research on the one hand and provides pharmaceutical partners with access to high-resolution technologies beyond commercial products on the other hand - both to their mutual benefit.

Similarly, partnering with hospitals offers the NIMSB access to diverse clinical samples and data critical for developing and testing innovative technologies. In addition, through collaboration with clinicians, the NIMSB can align its research with unmet medical needs. It enables a more manageable transition from preclinical research to clinical trials, thereby creating opportunities for new patient treatments.

These partnerships often evolve into long-term collaborations that ensure ongoing access to resources on both sides and a steady bidirectional stream of clinical data, increasing the scope and impact of the NIMSB's and their partner´s research efforts.

2.2. Innovation and Revenue Generation (Group Part)

By offering its advanced technological capabilities in AI and single-cell multi-omics analysis as a service to pharmaceutical companies, the NIMSB positions itself as a valuable collaborator in the clinical trial process. This engagement strategy not only fosters TT paths and profit sharing but also catalyzes the development of the NIMSB´s cutting-edge technologies. Such collaborative efforts result in shared intellectual property and profits, generating significant added value for the NIMSB and its industry partners. This model goes beyond financial gain; it drives the NIMSB´s research into new areas of clinical trial innovation and contributes to developing more efficient and effective trial methods. Overall, this engagement represents a revenue stream and a platform for the NIMSB to apply its research in the real world and increase the impact and reach of its clinical trial work.

2.3. Enhancing Patient Outcomes and Credibility (Group Part)

Involvement in clinical trials offers the NIMSB a unique opportunity to enhance patient outcomes and solidify its credibility in the scientific community while accelerating its impact in healthcare. By actively participating in clinical trials, the NIMSB can directly contribute to improved patient care by applying its innovative technologies or community initiatives s.a. patient engagement workshops. This participation enables the validation and practical application of the NIMSB´s research and enhances its reputation as a well-respected and influential institution in the medical science community. The data collection and insights gained through the use of the NIMSB´s technologies in clinical trials provide valuable contributions to the field, advanced understanding, and new avenues for medical research. Additionally, the NIMSB can effectively bridge the gap between fundamental research and practical clinical applications by focusing its preclinical research towards transitioning to clinical trials. It represents a strategic move for the NIMSB to transition from basic research to product development, which is crucial for tangible health benefits (Bertero, interview, November 7, 2023). This progression showcases the NIMSB's commitment to advancing medical science and strengthens its role as a health-related research and innovation leader.

3. Practical Recommendations (Group Part)

In the strategic context of the NIMSB's involvement in clinical trials, it is evident that managing a CTU to conduct clinical trials directly is not feasible for the NIMSB. Instead, the NIMSB should leverage its strengths through strategic partnerships and high-impact,

collaborative research efforts. This approach is in line with the NIMSB´s broader objectives that are mentioned in the overall introduction chapter about the NIMSB. Given the vital role of clinical trials for testing and validating new therapeutic strategies for patients, the NIMSB´s commitment to clinical trials positions it to contribute significantly to developing and validating innovative health solutions. For the NIMSB to make a meaningful impact, a detailed roadmap outlining timelines and steps for clinical application is essential, aligning its capabilities with the evolving market needs and positioning it at the forefront of innovation in clinical trials. Key milestones of this roadmap are depicted in Figure 8 in Appendix 20. This forward-looking approach is vital to harnessing the full potential of the NIMSB´s technological advancements in the dynamic medical research landscape.

To reach the first milestone of such a roadmap and establish the NIMSB as a key player in clinical trials, the NIMSB´s focus must be preparing its technologies for clinical use. This is crucial for meeting the current and future demands of the clinical trials market, particularly in precision medicine and the integration of advanced technology. Thus, the NIMSB should prioritize ***(1) the development and analytical validation of its cutting-edge technologies***, especially single-cell multi-omics and AI. The NIMSB can refer to established guidelines like the “Guideline on bioanalytical method validation” (https://bit.ly/3tlaMZw) for a comprehensive understanding of necessary validation criteria. Subsequent collaboration with biobanks, or leveraging its own biobank for sample testing and validation, is essential to ensure the technologies´ clinical applicability.

For reaching a further milestone of said roadmap, after successful analytical validation, the NIMSB should start concentrating on addressing local clinical trial needs by offering holistic solutions encompassing both basic research and clinical applications to local entities, s.a. hospitals (CUF or Hospital da Luz) and pharmaceutical companies. This strategic

local engagement will not only showcase the NIMSB´s capabilities and strengthen its industry credibility but also lay the groundwork for its ***(2) contributions to translational research by offering accompanying research***. Once this local foundation is established, the NIMSB´s validated, cutting-edge technologies can be applied to clinical trial samples, offering in-depth analyses that enhance understanding of patient responses and complex biological pathways.

To reach the last milestone of said roadmap, the NIMSB can effectively address shortcomings in patient recruitment and patient retention for clinical trials by ***(3) developing companion diagnostics for stratifying patients***. By leveraging its technological strengths, particularly in single-cell multi-omics and artificial intelligence, the NIMSB can more accurately categorize patients - a process that requires complicated and lengthy developments. This approach can improve treatment outcomes and streamline patient recruitment by identifying specific patient subgroups who would benefit most from targeted therapies. This long-term focus reflects the evolving role of the NIMSB´s technologies, which are expected to become increasingly important in patient stratification.

In addition to offering single-cell multi-omics and AI data analysis, the NIMSB should address local challenges of technology integration and talent shortages in clinical environments. Collaborating with hospitals like CUF or Hospital da Luz, who expressed a need for AI and single-cell multi-omics expertise, the NIMSB can help integrate these technologies effectively. By providing educational training programs, the NIMSB can increase scientific capabilities and technology adoption in medicine. Furthermore, by working closely with clinicians, the NIMSB can align its preclinical research with clinical applications, enhancing the practical impact and relevance of its findings.

Following the path outlined above will give rise to a series of interesting new opportunities and generate synergies with potential partners. However, it is important to

acknowledge that this represents a relatively uncharted area, even for other research institutes. As NIMSB ventures into this new domain, several challenges must be carefully considered and addressed, incl. factors s.a. regulatory hurdles, talent shortages, and rising costs.

In conclusion, the NIMSB's strategic focus on advancing precision medicine through cutting-edge technology and strong healthcare collaborations will position the institute to make essential contributions to clinical trials. The NIMSB has great potential to significantly improve medical science and patient well-being by merging innovative research with practical healthcare applications. This will be an important step forward in the NIMSB's efforts to redefine clinical trial methodology and enhance healthcare progress.

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Section D: Forging Ties with Industry (Group Part)

As highlighted in preceding sections, forging ties with industrial partners is essential for cultivating a stellar reputation of becoming a state-of-the-art research institute for systems biology. Collaboration with industry is not just instrumental in securing the financial viability of the institute; it will lay the foundation for developing an excellent research program by funding capital-intensive elements, s.a. biobanking. These elements in turn will enhance NIMSB's distinctiveness and reciprocally augment the scientific progress of its industrial collaborators, especially in areas impacting patient outcomes.

This section aims to methodically articulate the significance of synergistic engagements between academic institutes and the industrial sector. After explaining what objectives and constraints NIMSB may have, different paths of collaboration with industry are highlighted and assessed. Subsequently, the requisite organizational frameworks that facilitate

effective knowledge transfer are exemplified, and different formats of technology communication are outlined. Lastly, this section will provide an overview of potential challenges and a future outlook coupled with practical recommendations.

1. The Importance of Collaboration Between Research and Industry (Group Part)

Over the past 50 years, there has been a significant increase in collaborative life science research agreements between corporations, academic institutions, and non-academic research institutions. This trend stems from a noticeable shift in corporate strategy; life science companies, after consistently scaling back their investments in early-stage research, are now actively seeking partnerships with universities and research institutes. By engaging with these (academic) institutions, they aim to tap into the top-tier expertise and specialized knowledge in various scientific fields, effectively outsourcing their need for foundational research and thus saving costs (Lutchen 2018). For research institutes, partnering with industry is essential to maintain sustainable operations. The significance of such collaboration is shown by the well-regarded Vlaams Instituut voor Biotechnologie (VIB) or Massachusetts Institute of Technology (MIT), where revenue generated from industry collaborations exceeds 15 percent and 20 percent respectively of their annual budget. Notably, all profits from these activities are directly reinvested into further research efforts, which in turn benefits the scientific outcomes and, conversely, the overall reputation of an institute (Durinx, interview, November 8, 2023) (Roberts, interview, December 4, 2023).

The outputs of these partnerships, however, are even more impactful, as translational biomedical research significantly contributes to economic growth, especially when considering the creation of jobs and new companies (Jacinto, interview, September 30, 2023). Moreover, collaboration increases the efficiency of translational processes and garners benefits in biomedical research (Portilla & Alving 2019). Thus, research and industry collaborations can accelerate the introduction of groundbreaking pharmaceuticals and medical technologies, yielding significant benefits for public health (Martin 2002).

2. NIMB'S Vision, Capabilities, and Objectives (Group Part)

For the impact of collaboration outcomes between industry and research institutes to be significant, partnerships need to meet the institutes' notion of its vision, capabilities, and overall objectives. Thus, the following sections propose collaboration models aimed at fulfilling the NIMSB's objectives of becoming a CoE in the field of Medical Systems Biology. Other underlying goals specifically relevant to this section include creating sustainable long-term employment for at least 200 individuals funded by the NIMSB's core budget or additional grants and laying the foundation to spin off several start-ups (Jactinto, interview, September 30, 2023). Hence, identifying ways to sustain as an institute, independent from subsidies in the long run, is crucial and needs to be considered a priority within the NIMSB team. Even though the NIMSB may have the capability of materializing single-cell multi-omics to clinical practice in Portugal faster, some constraints will need to be considered in the context of serving the industry (Teaming document). Next to the relatively small size of

this institute within Europe and beyond, the technology can at first be classified as a low Technology Readiness Level (TRL) ranging from TRL-1 to TRL-3 (Jacinto, interview, September 29, 2023) (Table 3, Appendix 21) thus making it at first challenging to be regarded by industrial partners (Section C) and to count on industry as a steady source of income. For the industry, it will be crucial to move up the TRL to stages like TRL 7; otherwise, the industry will consider it fundamental research with a very long timeline towards commercialization (Leal, interview, October 19, 2023). Such constraints will need to be considered for the strategic planning of industrial partnerships.

2.1. Partnership Scope Selection Process (Group Part)

The desired scope and depth of a partnership may depend on the specific technology and company. For instance, a research institute may opt for a singular, preferred industrial ally, securing steady funding but potentially sacrificing operational flexibility due to exclusive commitments. The AstraZeneca-Oxford collaboration is a prime illustration of such a model, underscoring, however, the necessity for a research institution to be highly esteemed to attract such exclusive partnerships. Most of the research institutes decide on a “crowdfunding” model, implying that there are several different potential partners and projects stemming from a case-by-case evaluation. This latter approach may result in a more mutually beneficial dynamic for the NIMSB, allowing greater flexibility and independence for both parties (Mouta, interview, November 3, 2023). Apart from the number of partnerships set up, there is, according to Christine Durinx, the Co-Managing Director of VIB, a general notion that the

ideal partnership should be long-term, partners are considered equal, and resources and skills are complementary (Durinx, interview, November 8, 2023).

In terms of relevant industries for an institute in the medical systems biology space, pharmaceutical and biotechnology players will undoubtedly be primary targets for industrial partnerships, considering their direct relevance. However, given systems biology's involvement in substantial data generation, it may be beneficial for the NIMSB also to consider collaborations with companies specializing in computational fields like big data and data analytics. Data analytics companies are likely to seek expertise in interpreting the complex datasets that systems biology produces (O'Beirne, interview, November 16, 2023).

2.1.1. The Impact of Spinouts beyond the NIMSB (Group Part)

The contribution of spinout infrastructure to industry is undeniably significant. However, its impact extends even further, positively influencing the entire local ecosystem surrounding it, which, as per section A, is crucial for the NIMSB. While there may be no institutional preference between licensing technology or forming spinouts, spinouts play a crucial role in enhancing an institute's prestige. Despite the higher risks and longtime horizons until payout associated with spinouts, particularly in medical fields, they significantly boost a region's attractiveness and economic standing by creating high-quality employment opportunities and drawing in skilled professionals, as well as domestic and international funding. They initiate a self-reinforcing cycle of growth. This cycle begins with fostering entrepreneurial mindsets, leading to the creation of an entrepreneurial hub. This hub, in turn, attracts additional startups, further amplifying job creation and increasing funding opportunities. This dynamic cycle not only benefits the immediate environment but also contributes to broader regional development (Dominguez, interview, November 8, 2023).

Given the NIMSB's ambition and philosophy of significantly contributing to economic growth, job creation, and the formation of new companies, the development of pathways leading to spinout formations is unquestionably a vital strategy.

2.1.2. Dual Communication Models (Group Part)

A well-structured TTO plays a crucial role in managing the dual dynamic of either proactively promoting an institute's capabilities to the industry (open communication) or allowing the industry to influence research for its benefit (closed communication). To navigate this dual role effectively, the institute must be flexible and proactive in communicating its knowledge and expertise (Vidal, interview, December 7, 2023). It should clearly articulate its high-level mission goals as well as the specific objectives of each research line. Simultaneously, the TTO should manage a portfolio of technologies and assets that are available for external collaboration (Santos, interview, November 14, 2023).

Industrial partners often pursue two main paths in collaborations: *"You want strategic collaborations with incredibly prominent figures in the field, or you need a specific collaboration because somebody has a specific model or a specific method that you want to tap into"* (Penney, interview, November 27, 2023), highlighting the necessity to develop specialized technologies that address the unmet needs of the industry. This could include services s.a. conducting genome analyses, managing and cataloging biosamples (section B), and clinical trial support tools (section C). This strategy is especially pertinent to the NIMSB, considering the potentially lengthy process involved in recruiting such prominent figures.

Additionally, the innovation office is responsible for protecting intellectual property and serving as a bridge between the institute and various external stakeholders. By adeptly handling both inward and outward engagement, the NIMSB's TTO can play a pivotal role in

advancing the institute's research and innovation goals (Santos, interview, November 14, 2023).

3. Challenges (Group Part)

Setting up a successful TT framework at the NIMSB will undoubtedly come with challenges. Firstly, given that Systems Biology is a relatively new science and lacks a substantial track record in drug development (O'Beirne, interview, November 16, 2023), the NIMSB's technologies might initially be at a low TRL. Therefore, setting realistic expectations for the timeframe of translating systems biology research into marketable products or licensed deals is crucial. Moreover, there is a need for the NIMSB to offer novel and distinct scientific contributions that set it apart from industry capabilities despite the industry's larger financial resources (Vidal, interview, December 7, 2023). Secondly, being based in Portugal presents challenges due to limited university-industry linkages in the national economy (Teixeira and Monteiro 2018), yet this also opens opportunities for the NIMSB to bridge this gap. Thirdly, the success in translation, particularly for spinouts, greatly depends on the entrepreneurial mindset within the NIMSB's staff, a trait found challenging to cultivate in the scientific community. (Roberts, interview, December 4, 2023)

4. Practical Recommendations (Group Part)

Drawing upon the insights of various decision makers from the perspective of renowned life science research institutes and universities as well as relevant, influential pharmaceutical representatives, allows for a comprehensive framework of recommendations

on how the NIMSB can forge ties to the industry for ensuring long-term success. Long-term success in this context is defined as reaching the NIMSB's research, societal, and financial goals.

The insights and recommendations from this study can be organized into two primary strategic visions for guiding the NIMSB's operations and a key recommendation for a foundational structure to support these strategies (Figure 9, Appendix 27).

First, the NIMSB should position itself as ***fulfilling a role as a connector*** in the single-cell multi-omics field, fostering a collaborative environment, mutual learning, and innovation. It should pursue dynamic, long-term, and equitable industry partnerships and aspire to become a hub in the field. There is an increasing trend of companies seeing value to be connected within an innovation ecosystem (Roberts, interview, December 4, 2023). Further, there is sufficient evidence that both industry players and institutes prefer long-term, ongoing collaboration. The NIMSB should provide a platform facilitating connections between industry partners, researchers, governmental institutions, investors, and startups, e.g., in terms of organizing events, meet-ups, etc. Fostering an industry partnership model or ongoing strategic collaboration and integrating them into the NIMSB ecosystem may reflect an ideal way to ensure a constant, long-term connection and exchange.

The second is to position the NIMSB as a leader in ***driving entrepreneurship***. It should actively support a sustainable and diverse spinout pipeline, maximizing opportunities for growth and impact. Moreover, focusing on providing adequate tools and support for spinouts is key - e.g., through connecting entrepreneurs with potential investors has proven to work well in other institutes. Given the resource-intensive nature of these support systems, the NIMSB needs to explore how it can indirectly benefit, s.a. becoming a shareholder through external trustee arrangements. Effectively managed, a thriving spinout ecosystem can

significantly align with the NIMSB's objectives in economic and scientific contributions, thereby yielding substantial societal benefits in the Lisbon region and beyond.

Lastly, the successful implementation of the previous two recommendations mandates a ***strong operational and agile foundation***, ensuring the NIMSB is administratively effective and strategically positioned for long-term success. One element of this is a well-functioning TTO both in terms of size and the appropriate governance structure and backgrounds in place. To build ties with the industry successfully, it is crucial to attract scientists, professors, transfer managers, and decision-makers within the NIMSB who, in the best case, have experience working in or with the industry to understand their needs. Next, the NIMSB should attract profiles that are driven by NIMB's visions mentioned above, which is why the proper external articulation of these values is imperative. Furthermore, the NIMSB will need to set tangible, goal-oriented KPIs that are not just tracking research-focused goals but measure status in terms of industry ties, e.g., number of industry partnerships or TRL progression. The NIMSB's strategic focus should be consistently directed towards building up and diversifying its portfolio with an eye on long-term sustainability beyond the initial funding. For example, the NIMSB should proactively focus on setting up the requisite infrastructure for facilitating spinout creation since the return on investment may be stretched for several years; hence, initiating this process in the early stages of the institute's development is advisable to ensure a robust portfolio in the future. While maintaining its autonomy, the NIMSB should consider partnerships with independent TT companies to reduce the high costs of establishing a wide range of industry collaboration opportunities, enabling it to achieve its vision of a diverse and dynamic portfolio.

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Final Conclusion (Group Part)

To summarize, the preceding analysis substantially contributes to the overall development of a foundational framework instrumental in the NIMSB's overarching developmental strategy. It lays the groundwork for further investigations and complements the comprehensive business plan. The four components can be seen as fundamental building blocks of the "House of the NIMSB" (Figure 10 in Appendix 28). Together with other essential building blocks, they constitute the foundational structure of the house, collaboratively aiding the NIMSB in realizing its vision of establishing a prominent position within the research ecosystem. The key findings of each focus topic can be summarized as follows:

(1) At its core, research is fundamentally driven by cooperative initiatives. Hence, engaging in local and global partnerships is crucial for the NIMSB to establish its position through the contribution of its unique capabilities and effective utilization of available resources.

(2) Centralized collaborative biobanking has the potential to expedite and bolster the NIMSB's research goals while also making a significant contribution to the research community.

(3) The NIMSB can distinguish itself among peer institutions by leveraging its cutting-edge technologies in clinical trials. Embracing a forward-thinking approach positions the NIMSB uniquely within the evolving landscape of clinical trials. It equips the institute to address future challenges and opportunities in the healthcare community.

(4) The NIMSB will achieve its outlined objectives by becoming an innovation and entrepreneurship hub and forging long-term and equitable industry partnerships while building on a strong operational foundation beyond initial funding.

Adopting these recommendations will position the NIMSB at the forefront of healthcare research and innovation, enabling the institute to effectively meet its research objectives while making a profound and lasting impact to the healthcare community.

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Appendices

Appendix 1: List of Abbreviations

AI	Artificial Intelligence
BBMRI	Biobanking and BioMolecular resources Research Infrastructure
BRC	Biological Resource Centers
CAGR	Compound Annual Growth Rate
CEDOC	Centro de Estudos de Doenças Crónicas
CEIC	Ethics Committee in Portugal
CEO	Chief Executive Officer
CF	Champalimaud Foundation
CHRC	Comprehensive Health Research Centre
CINTESIS	Center for Health Technology and Services Research
CNPD	Comissão Nacional de Proteção de Dados
CRG	Centre for Genomic Regulation
CRO	Contract Research Organization
CTIS	Clinical Trials Information System
CTO	Career, Education, and Training Office
CTU	Clinical Trials Unit
DCT	Decentralized Clinical Trials
DNA	Deoxyribonucleic acid
EBI	European Bioinformatic Institute
EEA	European Economic Area
ELSI	Ethical, Legal, Social Issues
ERIC	European Research Infrastructure Consortium
ESBB	European, Middle Eastern & African Society for Biopreservation and Biobanking
EU	European Union

FFPE	Formalin-fixation and paraffin-embedding
FIMM	Finnish Institute for Molecular Medicine
GDPR	General Regulation on Protection of Personal Data
HR	Human Resources
HUB	Hannover Unified Biobank
IARC	International Agency for Research on Cancer
iBET	Institute of Experimental and Technological Biology
IEC	Independent Ethics Committee
IGC	Instituto Gulbenkian de Ciencia
ILP	Industry Liaison Program
IMM	Institute of Molecular Medicine
IMP	Research Institute of Molecular Pathology
IP	Intellectual Property
IPM	Industry Partnership Model
IPO	Instituto Português de Oncologia
IRB	Institutional Review Board
IRB	Institute for Research in Biomedicine in Barcelona
ISB	Institute for Systems Biology
ISBER	International Society for Biological and Environmental Repositories
ISO	International Organization for Standardization
ISPUP	Instituto de Saúde Pública da Universidade do Porto
IT	Information technology
ITQB	Instituto de Tecnologia Química Biológica António Xavier
KI	Karolinska Institute
KOL	Key Opinion Leader
KPI	Key Performance Indicator
MBA	Master of Business Administration
MDC	Max Dellbrück Center
MHH	Hannover Medical School
MIT	Massachusetts Institute of Technology
MoU	Memorandum of Understanding
MTA	Material Transfer Agreement
NISMB	Nova Institute for Medical Systems Biology
NMS	Nova Medical School

OECD	Organization for Economic Cooperation and Development
R&D	Research & Development
RNA	Ribonucleic acid
RWD	Real-World Data
RWE	Real-World Evidence
TRL	Technology Readiness Level
TT	Technology Transfer
TTO	Technology Transfer Office
UCD	University College Dublin
UK	United Kingdom
VIB	Vlaams Institute voor Biotechnologie
WHO	World Health Organization

Appendix 2: Definitions

(1) Retrospective research: Retrospective research involves the analysis of pre-existing data and/or biological samples (Junod 2010, 1).

(2) Omics data: Omics data refers to data conceived in scientific disciplines, called “omics”, which is related to the high-throughput measurement of biological molecules. Various fields of study can be categorized as omics. Examples encompass proteomics, transcriptomics, genomics, metabolomics, lipidomics, and epigenomics. These terms refer to comprehensive investigations of proteins, RNA, genes, metabolites, lipids, and methylated DNA or changed histone proteins in chromosomes, respectively (Micheel CM, Nass SJ, Omenn GS 2012, 1)

(3) FFPE (formalin-fixation and paraffin-embedding): Formalin fixation and paraffin embedding (FFPE) are commonly used techniques to preserve tissue specimens for

diagnostic pathology. However, formalin fixation causes significant fragmentation of nucleic acids (Berrino et al. 2020, 173).

(4) Retrospective studies: A retrospective study is a clinical study that empirically examines the effectiveness of a medical treatment procedure or the factors leading to a disease, starting from the outcome identified at the beginning of the study (DocCheck 2014).

(5) Biomarkers: A biomarker is an objective and measurable indicator of a physiological or pathological process or a response to a therapeutic intervention (European Medicine Agency, n.d.).

(6) Companion diagnostic: A companion diagnostic is a medical device, usually an in vitro diagnostic (IVD), that is critical to the safe and effective use of a corresponding drug or biological product. Its functions include identifying patients who will benefit most from a particular therapy, detecting patients at higher risk for serious adverse events, and monitoring treatment responses to adjust safety and efficacy (Food and Drug Administration 2023b).

(7) Technology Transfer (TT): is formally described as the movement of scientific and technological research outcomes to the marketplace and broader society, incl. the relevant skills and methods (European Commission 2012)

Appendix 3: Method

A total of 44 qualitative semi-structured interviews were conducted with professionals from various sectors, incl. research- and academic institutes, hospitals, biobanks, pharmaceutical companies, and governmental institutions. The objective of these interviews was to gain a comprehensive understanding from a diverse range of experts in these fields. A list of all conducted interviews, incl. interviewee names, company/institutional names, job roles, and contact information (i.e., LinkedIn profile link and email address), is attached in Appendix 4.

Identification and Recruitment of Participants

Participants were recruited through a rigorous, independent process, primarily utilizing LinkedIn and direct email contact. Our selection strategy ensured a diverse pool of interviewees, encompassing roles, s.a. Principal Investigators, Senior Researchers, Vice Presidents, Heads of Partnerships, and Clinical Research Coordinators. The selection and recruiting was made with minimal reliance on the NIMSB’s and our supervisor's network to avoid self-selection bias and ensure a broad representation of perspectives.

Interview Structure and Process

Interviews were conducted between October 10th and December 13th, 2023, each lasting approximately 30 to 90 minutes. The integrated transcription tool of Microsoft Teams was utilized to accurately document the interviews. Handwritten note-taking was additionally used when deemed essential. The interviews were semi-structured to provide flexibility in delving into the expertise of each participant. Thereby, questions could be modified

dynamically, honing in on the topics where the interviewee demonstrated the highest level of expertise and reliability. This method reduced response bias by limiting participants' likelihood of delivering replies based on what they believed was desired.

Appendix 4: Conducted Interviews

No.	Current Organization	Name	Current Position	Date of Interview	Contact
1	AccelBio	Barbara Gomes	CEO	October 27, 2023	**LinkedIn:** https://www.linkedin.com/in/barbaraslgomes/ **Mail:** barbaragomes@accelbio.pt
2	Almac Group	Richard Kennedy	Global Vice President and Medical Director	October 12, 2023	**LinkedIn:** https://www.linkedin.com/in/profkennedy/ **Mail:** richard.kennedy@almacgroup.com
3	Ascenion	Esther Lange	Industry Liaison & Technology Manager	November 27, 2023	**LinkedIn:** https://www.linkedin.com/in/esther-maria-lange-1069a112/ **Mail:** lange@ascenion.de
4	Ascenion	Céline Christiansen-Mensch	Technology Scout	November 27, 2023	**LinkedIn**: https://www.linkedin.com/in/cechri/ **Mail:** lange@ascenion.de
5	AstraZeneca	Jacopo Biasetti	Associate Director - Systems Medicine	December 16, 2023	**LinkedIn**: https://www.linkedin.com/in/jacopo-biasetti-ph-d-5a660a65/ **Mail:**
6	Bayer	Theresa Kolben	Global Head Early Clinical Development Oncology	October 17, 2023	**LinkedIn:** https://www.linkedin.com/in/theresa-kolben-prof-dr-med-0278a811b/ **Mail:** theresa.kolben@bayer.com
7	Bayer Pharmaceuticals	Marina Penney	Vice President, Global Head of Oncology Precision Medicine	November 27, 2023	**LinkedIn:** https://www.linkedin.com/in/marina-penney-aa2b9a6/ **Mail:** christiansen-mensch@ascenion.de

8	BBMRI-ERIC	Saba Abdulghani	Head of Biobanking Development	November 22, 2023	**LinkedIn:** https://www.linkedin.com/in/dr-saba-abdulghani-38139bb/ **Mail:** saba.abdulghani@bbmri-eric.eu
9	BIMSB	Ashley Sanders	Group Leader	December 13, 2023	**LinkedIn**: https://www.linkedin.com/in/ashleydsanders/ **Mail**: ashley.sanders@mdc-berlin.de
10	Casa di Cura Privata del Policlinico	Melania Filareti	Biobanker	December 4, 2023	**LinkedIn:** https://www.linkedin.com/in/melania-filareti-880bb9109/?originalSubdomain=it **Mail:** m.filareti@casadicuraigea.it
11	Centre for Genomic Regulation (CRG)	Diana Dominguez	New Ventures Manager	November 8, 2023	**LinkedIn:** https://www.linkedin.com/in/diana-dom%C3%ADnguez-rodr%C3%ADguez-phd-7a349b192/ **Mail:** diana.dominguez@crg.eu
12	Champalimaud Foundation (Biobank)	Mireia Castillo	Responsible for Biobank	November 22, 2023	**LinkedIn:** **Mail:** mireia.castillo@research.fchampalimau
13	Champaulimaund Foundation	Joana Lamego	Head of Strategic Research Development	November 22, 2023	**LinkedIn:** https://www.linkedin.com/in/joana-lamego-10741a26/ **Mail:** joana.lamego@research.fchampalimaud.org
14	Charité	Verena Benz	Head of Match&Connect	October 13, 2023	**LinkedIn:** https://www.linkedin.com/in/dr-verena-benz-b018a756/ **Mail:** verena.benz@bih-charite.de
15	Charité	Alexandra Stege	Operational Manager	December 12, 2023	**LinkedIn**: https://www.linkedin.com/in/alexandra-eva-stege/?originalSubdomain=de **Mail**: alexandra.stege@charite.de
16	Charité BIH	Tim Huse	Head of BIH Digital Labs with Digital Health Accelerator	November 17, 2023	**LinkedIn:** https://www.linkedin.com/in/timhuse/ **Email:** tim.huse@bih-charite.de
17	CUF	Ingrid Gouveia	Group Lead - Clinical Research Coordinator	November 14, 2023	**LinkedIn:** https://www.linkedin.com/in/ingri

					dgouveia/?originalSubdomain=pt **Mail:** ingrid.gouveia@jmellosaude.pt
18	CUF Academic Center	Maria Barros	Director	October 31, 2023	**LinkedIn:** https://www.linkedin.com/in/maria-barros-387803a/?originalSubdomain=pt **Mail:** maria.jose.barros@jmellosaude.pt
19	EU Life	Marta Dias Agostinho	Executive Director	October 24, 2023	**LinkedIn:** **Mail:** marta.agostinho@eu-life.eu
20	Hospital da Luz	Francisca Leite	Executive Director	October 18, 2023	**LinkedIn:** https://www.linkedin.com/in/francisca-leite-217505/ **Mail:** francisca.leite@luzsaude.pt
21	IDIBAPS	Michela Bertero	Strategy Director	November 7, 2023	**LinkedIn:** https://www.linkedin.com/in/michela-bertero-23a2584/?originalSubdomain=es **Mail:** BERTERO@recerca.clinic.cat
22	Innovation & Incubation Center Leuven	Michael De Blauwe	Chairman of the Board	November 21, 2023	**LinkedIn:** https://www.linkedin.com/in/michaeldeblauwe/ **Mail:** deblauwemichael@gmail.com
23	Institute for Molecular Medicine Finland (FIMM)	Mari Anneli Kaunisto	Senior Researcher	November 10, 2023	**LinkedIn:** https://www.linkedin.com/in/mari-kaunisto/ **Mail:** mari.kaunisto@helsinki.fi
24	Instituto de Medicina Molecular // Biobanco IMM	Sergio Dias	Principal Investigator	October 12, 2023	**LinkedIn:** https://www.linkedin.com/in/s%C3%A9rgio-dias-9903352/?originalSubdomain=pt **Mail:** sergiodias@medicina.ulisboa.pt
25	ITBQ	João Crespo	Dean	October 10, 2023	**LinkedIn:** **Mail:** jgc@fct.unl.pt
26	ITQB NOVA	Miguel Santos	Invited Principal Investigator - StartUp Research Coordinator	November 14, 2023	**LinkedIn:** https://www.linkedin.com/in/miguel-santos-1755295/ **Mail:** miguel.santos@unl.pt
27	Karolina Institute	Mark Divers	Retired Director	November 15, 2023	**LinkedIn:** https://www.linkedin.com/in/mark

	Biobank				-divers-61761711/ **Mail:** mark.divers@ki.se
28	Massachusetts Institute of Technology (MIT)	John C. Roberts	Executive Director, MIT Corporate Relations (Interim)	December 4, 2023	**LinkedIn:** https://www.linkedin.com/in/john-roberts-97b8b06/ **Mail:** roberts5@mit.edu
29	Max Delbrück Center (MDC)	Stan Gorski	Science Strategy	October 11, 2023	**LinkedIn:** https://www.linkedin.com/in/stan-gorski-8913ab248/ **Mail:** stan.gorski@mdc-berlin.de
30	Max Delbrück Center (MDC)	Marie Vidal	Industry and innovation Manager	December 12, 2023	**LinkedIn:** https://www.linkedin.com/in/marie-vidal-phd-mba-14892643/?originalSubdomain=de **Mail:** Marie.Vidal@mdc-berlin.de
31	Max Delbrück Center (MDC)	Antonia Klein	Innovation and Technology Manager	December 13, 2023	**LinkedIn:** https://www.linkedin.com/in/antonianicoleklein/ **Mail:** Antonia.Klein@mdc-berlin.de
32	Max Delbrück Center (MDC)	Uta Elisabeth Höpken	Group Leader; PhD at Max Delbrueck Center for Molecular Medicine	November 28, 2023	**LinkedIn:** https://www.linkedin.com/in/priv-doz-dr-uta-elisabeth-h%C3%B6pken-7a89106a/ **Mail:** Uta.Hoepken@mdc-berlin.de
33	Medical University of Bialystok // ISBER	Anna Michalska-Falkowska	Deputy Director of Quality Management in Biobank & Clinical Trial Coordinator	October 17, 2023	**LinkedIn:** https://www.linkedin.com/in/anna-michalska-falkowska/?originalSubdomain=pl **Mail:** anna.michalska-falkowska@umb.edu.pl
34	Nova Medical School	Antonio Jacinto	Future Director of NIMSB	September 30, 2023	**LinkedIn:** https://www.linkedin.com/in/antonio-jacinto-a584509/ **Mail:** antonio.jacinto@nms.unl.pt
35	Nova Medical School	Patricia Calado & Mariana CC Silva	Vice Dean for Research	October 26, 2023	**LinkedIn:** https://www.linkedin.com/in/patriciacalado/ **Mail:** patricia.calado@nms.unl.pt
36	Oeiras City	Elisabete Baiôa Brigadeiro	Administration	October 18, 2023	**LinkedIn:** **Mail:** elisabete.brigadeiro@oeiras.pt

37	Ophiomics	Jose Leal	CEO	October 19, 2023	**LinkedIn:** https://www.linkedin.com/in/pereiraleal/ **Mail:** jleal@ophiomics.com
38	Ophiomics	C. Gaspar	Business Development	November 1, 2023	**LinkedIn:** **Mail:** cgaspar@ophiomics.com
39	Roche	Joao Mouta	Principal Global Medical Leader - Breast and Gynecological Cancers	November 3, 2023	**LinkedIn:** https://www.linkedin.com/in/jo%C3%A3o-mouta-60050a57/ **Mail:** joao.mouta@roche.com
40	Universidade Nova de Lisboa (Lisbon New University)	Rui Manuel Silva	Innovation, Knowledge Valorisation, and Intellectual Property Officer	November 8, 2023	**LinkedIn:** https://www.linkedin.com/in/ruimrsilva/ **Mail:** rui.silva@unl.pt
41	University College Dublin (UCD)	Ciaran O'Beirne	Manager, Knowledge Transfer	November 16, 2023	**LinkedIn:** https://www.linkedin.com/in/ciaran-o-beirne-52b42141/ **Email**: ciaran.obeirne@ucd.ie
42	Victorian Cancer Biobank / ISBER	Wayne Ng	Director at Large	October 25, 2023	**LinkedIn:** https://www.linkedin.com/in/wayne-ng-844654a8/?originalSubdomain=au **Mail:** Wayne.Ng@cancervic.org.au
43	Virtuleap/ VectorB2B	Bebiana Moura	Head of Partnerships	October 18, 2023	**LinkedIn:** https://www.linkedin.com/in/bebiana-moura/?originalSubdomain=pt **Mail:** bebianamoura@gmail.com
44	Vlaams Instituut voor Biotechnologie (VIB)	Erwin Sablon	Head of Business Development	October 19, 2023	**LinkedIn:** https://www.linkedin.com/in/erwin-sablon-27b4115/ **Mail:** erwin.sablon@vib.be
45	Vlaams Instituut voor Biotechnologie (VIB)	Sofie Coleus	Business Development Manager	November 16, 2023	**LinkedIn:** https://www.linkedin.com/in/sofie-coelus-7476a628/ **Mail:** sofie.coelus@vib.be

Appendix 5: The BIMSB's Ecosystem

The Berlin Institute for Medical Systems Biology (BIMSB) is a specialized research unit of the MDC, focusing on merging systems biology with state-of-the-art technology for biomedical research advancement (Max Delbrück Center 2023).

Local Collaborations

Regarding the local partnerships of the BIMSB, the research center is based in a university building on the Life Science Campus, near different important research institutions. The key partners of the BIMSB include, among others, different renowned academic centers, s.a. the Charité and the Humboldt University. Additional local collaborators are research centers not only from the medical field but also from other areas, s.a. mathematics, physics, and data science, e.g., the international Helmholtz Einstein School. Another important partnership is with the Berlin Institute of Health (BIH), a biomedical research institute specializing in translational research and precision medicine. The cooperation between BIH, Charité, and the BIMSB is particularly relevant to transfer research findings into valuable therapies and technologies. Additionally, the MDC manages the Helmholtz Einstein School Association, an alliance that not only includes the BIMSB but also collaborates with a center for digitalization and a funding organization. As part of this collaboration, the partners offer Ph.D. programs with universities and a hospital. These partnerships are focused on training young talents in diverse research areas. Likewise, the NIMSB is set to become part of a diverse university ecosystem, in part through its collaboration with the Nova University. This extensive network, encompassing various academic fields, will be further explained in detail (Max Delbrück Center 2023).

National Collaborations

Among others, the BIMSB's national collaborations involve associations, s.a. the Single Cellomics Germany (SCOG). The SCOG is a program between the BIMSB, the Institute of Computational Biology, and Saarland University. The partnership aims to collaboratively develop computational models through joint research projects. Moreover, the BIMSB participates in several other national networks that are engaged in joint research into rare diseases and complex data analysis, e.g., the German Epigenome Programme and the German Network for Bioinformatics Structure (DEEP 2023; German Network for Bioinformatic Infrasture 2023; Max Delbrück Center 2023).

International Collaborations

At a European level, BIMSB is part of diverse collaborative networks. The LifeTime Association, for example, is jointly managed by the MDC and the Institute Curie, incl. 100 research centers in Europe. The program focuses on achieving decisive advances in medicine through collaboration. Furthermore, the research institute is part of the circTrain program, offering joint training in specific research areas. Countries, s.a. Spain, Italy, Denmark, the Netherlands, and Germany participate in this partnership. In addition, the BIMSB is involved in global alliances, focusing on progress in specialized research areas. Jointly, the BIMSB, the New York University, and the Center for Genomics and Systems Biology offer doctoral programs in which students are trained in certain research areas. Moreover, the MDC, together with the German-Israeli School and an Israeli research center function as mentors for students in shared laboratories abroad (Max Delbrück Center 2023).

Appendix 6: IRBS's Ecosystem

The Institute of Biomedical Research (IRB) in Barcelona mainly focuses on cancer research. The IRB is based in a science park near different technology institutions (IRB Barcelona 2023).

National Collaborations

Looking at national cooperations, the IRB works, among others, together with the Spanish Association Against Cancer. Jointly, the partners address one of the greatest medical challenges by involving diverse expertise. Moreover, the institute is part of a program that focuses on translating research findings into therapies, drugs, and technologies (Translational Research and Innovation Program). Within the scope of this initiative, one of the most relevant Spanish banks, Caixa, financially supports the IRB and the Catalan Health Government (CaixaBank 2023; IRB Barcelona 2023). As a part of the program, further objectives are being pursued among the partners. On the one hand, new research group leaders are jointly chosen and trained in key medical areas. On the other hand, the IRB and regional hospitals are collaboratively designing new models and therapies for patients. Besides, an external management board monitors the program within the joint laboratories. Moreover, the board members collaborate with universities from different fields and specialized research centers (IRB Barcelona 2023).

International Collaborations

On a global stage, the IRB receives financial support from individual citizens, a wide range of companies, and the Spanish government. The IRB maintains numerous international

partnerships, particularly with research centers, universities, and hospitals, e.g., in Japan and the Netherlands (IRB Barcelona 2023).

Appendix 7: Other Types of Collaborations

Collaboration with legal advisory firms is essential for addressing diverse regulatory challenges within research (Dìas, interview, October 12, 2023; Gorski, interview, October 11, 2023; Leal, interview, October 19, 2023; Santos, interview, November 14, 2023). Cooperating with a legal consultant is particularly important to facilitate the NIMSB's partnerships with external stakeholders, making them more attractive for collaboration (Gorski, interview, October 11, 2023). Furthermore, it should be considered to seek individualized advice on patent rights and intellectual property to properly assist researchers in turning their findings into profitable and valuable solutions (Gomes, interview, October 27, 2023; Leal, interview, October 19, 2023). Individualized consultancy offers advantages but can also be accompanied by considerable costs. Yet, a deficiency in legal conditions has been identified at the local level. Looking at larger cities, s.a. Lisbon and Porto, specialized legal companies in healthcare can be found. The choice between multiple small legal advisors and a single major firm depends on the NIMSB's specific goals and financial considerations. Notably, CMS Portugal and Vieira de Almeida are important legal firms in this sector, each offering a blend of expertise and comprehensive healthcare-related services (CMS 2023; Vieira de Almeida 2023).

Moreover, as highlighted in the chapter "International Best Practices" and further affirmed by the interviews, (2) international collaborations are fundamental to achieving research excellence. International partnerships expand the scope of innovation and increase

the variety of capabilities, thereby broadening the range of new opportunities available. It is important to mention that many relevant researchers and successful scientific papers have their roots in international collaborations (Crespo, interview, October 10, 2023; Sablon, interview, October 19, 2023). To achieve sustainable strategic positioning, it is advisable to evaluate the collaborative models discussed earlier with international partners, addressing the needs already mentioned. Furthermore, this approach will significantly enhance the Institute's global presence in the research arena.

For example, to effectively address the diverse specimen needs in precision medicine and complex sample transfer regulations in Portugal, it is essential to consider forming partnerships with international biobank networks, facilitating such processes (Gorski, interview, October 11, 2023; Jacinto, interview, September 29, 2023; Leal, interview, October 19, 2023; Ng, interview, October 25, 2023). In pursuing collaborations, the NIMSB might consider partnerships with acknowledged biobank networks like the European, Middle Eastern and African Society for Biopreservation and Biobanking (ESBB) and the International Society for Biological and Environmental Repositories (ISBER) (ESBB 2023; ISBER 2023). These alliances could provide access to a diverse range of samples. However, the challenge lies in offering equivalent value in return to these extensive biobank networks. Initially, focusing on strengthening local collaborations with entities connected to international biobanks can facilitate access to these global connections (Jacinto, interview, September 29, 2023).

Additionally, collaborative research projects and exchange programs for researchers with various renowned research institutes, such as the Research Institute for Molecular Pathology (IMP) in Vienna and the Broad Institute in Massachusetts, both top-notch in single-cell research, could be advantageous (Broad Institute 2023; IMP 2023). Furthermore,

the NIMSB should consider partnering with relevant universities abroad to provide international collaborative training and exchange programs. For instance, students from partner faculties are offered to conduct parts of their PhD or Master's studies at the NIMSB, while researchers teach specific courses at foreign institutions (Michael and Balraj 2003, 133). This approach would not only encourage shared learning and mutual introductions but also enhance the research institute's attractiveness to researchers, students, and potential partner organizations. As a result, it would substantially contribute to fostering a globally connected academic community (Leal, interview, October 19, 2023). A variety of prestigious and internationally recognized research universities, such as the Charité, which is closely partnered with the MDC and thus more accessible, along with other universities, can be considered as collaborators (Charité 2023). While renowned organizations might offer broader visibility and cutting-edge education and research, smaller institutions might be more motivated to quickly establish collaborations to expand their networks. Furthermore, forming international partnerships, it is important to consider the unique advantages each country offers. For example, Israel's regions, known for entrepreneurial skills, provide distinct capabilities beneficial for collaborations (Benz, interview, October 13, 2023).

Appendix 28: The House of NIMSB