Setting Up A State-Of-The-Art Laboratory In Resource Limited Settings: A Case Study Of The Biomedical Science Research And Training Centre In Northeast Nigeria

Murtala Bindawa Isah,[1, 2] Zaid Muhammad, [1, 3, 4] Mohammed Musa Lawan,[1, 5] Abdulrahman I. Alkhamis, [1, 6, 8] Baba W. Goni, [1, 7, 9] Sebastian S. Oakley,[1, 3] Karen Marshall, [1, 3] Renée Hartig, [1, 4, 10, 11, 12, 13] Issa S. R, [1, 4, 14, 15] Yoshimatsu T, [1, 3, 4, 16] André Maia Chagas, [1, 3, 4] & Mahmoud B. Maina [1, 3, 4]*

[1]Biomedical Science Research and Training Centre, Yobe State University, Damaturu, Yobe State, Nigeria
[2] Department of Biochemistry, Umaru Musa Yar'adua University, Katsina, Nigeria
[3] Sussex Neuroscience, School of Life Sciences, University of Sussex, Brighton, UK
[4] TReND in Africa (www.TReNDinAfrica.org), Brighton, UK
[5] Department of Chemistry, Yobe State University, Damaturu, Nigeria.
[6] Department of Human Physiology, College of Medical Sciences, Yobe State University, Damaturu, Yobe State, Nigeria
[7] Yobe State University Teaching Hospital Damaturu, Yobe State, Nigeria
[8] Department of Human Physiology, Faculty of Basic Medical Sciences, Ahmadu Bello University, Zaria, Kaduna State, Nigeria
[9] Department of Medicine, College of Medical Sciences, University of Maiduguri, Maiduguri, Borno State, Nigeria
[10]Max Planck Institute for Biological Cybernetics, Tübingen, Germany
[11]Functional and Comparative Neuroanatomy Laboratory, Werner Reichardt Centre for Integrative Neuroscience, Eberhard Karl University of Tübingen, Tübingen, Germany
[12]Department of Psychiatry and Psychotherapy, University Medical Center, Johannes Gutenberg University Mainz, Mainz, Germany
[13]Center for Biomedical Imaging and Neuromodulation, Nathan Kline Institute for Psychiatric Research, Orangeburg, NY, United States
[14]Maintenance of the nervous system & behaviour, Brain Plasticity Unit, CNRS, ESPCI Paris, PSL Research University, Paris, France
[15]Laboratoire de biologie et modélisation de la cellule, ENS de Lyon, Lyon, France
[16]Department of Ophthalmology and Visual Sciences, Washington University in St Louis School of Medicine, St Louis, USA.

Correspondence: Mahmoud B. Maina mahmoud.maina@biortc.com and m.bukar-maina@sussex.ac.uk

Abstract

African science has substantial potential, yet it grapples with significant challenges. Here we describe the establishment of the Biomedical Science Research Centre (BioRTC) in Yobe State, Northeast Nigeria, as a case study of a hub fostering on-continent research and describe strategies to surmount some of these barriers. We detail the steps taken to establish BioRTC, emphasising the critical importance of stakeholder engagement, community involvement, resource optimisation, and collaborations. Although we are in the early stages of our journey, our experience can nonetheless serve as a guide to others embarking on similar endeavours in resource-limited settings. We invite the support and collaboration of those who share our vision and believe in our potential.

Keywords: African science, Research infrastructure, Resource-limited settings, Genetic Diversity, Ethnic Diversity, Biodiversity

1. Introduction

Africa, home to nearly a third of the global population, predominantly youthful and diverse, is endowed with a range of climates and rich natural resources. Despite these advantages, internal and external factors have hampered the continent's potential for development, causing it to lag behind other regions [1]. Widespread issues like political instability, poverty, poor education quality, and preventable diseases continue to plague the African continent [1]. In addressing these problems, scientific research is poised to play a significant role [2, 3], by providing evidence-based solutions that inform policies and actions and serve as a neutral ground for civilised discourse.

Nigeria, Africa's most populous country with a robust GDP [4], exemplifies the struggles and potential of scientific research within the continent. Although a top contributor to Africa's scientific literature [5, 6], the quality of its research often lags behind its global northern counterparts [7]. This gap can be traced back to various factors, including insufficient funding—Nigeria invests only about 0.13% of its GDP in research and development, less than a quarter of the average expenditure by other Sub-Saharan African countries [4].

The situation in Northeast Nigeria, a region that is rebounding after a decade of political and security-related challenges, is unique. The region is marked by remarkable resilience, strategic location, rich cultural diversity, and incredible biodiversity, both in terms of human and animal populations [8, 9]. This biological diversity provides a rich landscape for genetic studies and offers unique insights into both animal diseases and the development of novel animal models for biomedical research. It also allows for in-depth exploration of human diseases, such as malaria and mental health and brain disorders, the incidence of which was partly influenced by a decade of insecurity in the region [10, 11]. To nurture and support the region's development, the Nigerian government established the North East Development Commission [12], aiming to transform challenges into opportunities and position Northeast Nigeria as a beacon of resilience and a future hub for societal development through education and healthcare delivery.

In the past decade, Africa's research capacity has made significant strides. The number of researchers (measured as full-time equivalents per million inhabitants) rose from 14 to 20 between 2014 and 2023 [13]. Moreover, Africa's contribution to global health research output, as gauged by publication count, nearly doubled since 2000 [14]. These statistics suggest a positive return on efforts to bolster Africa’s research capacity, yet they also highlight Africa's underrepresentation in global research. Addressing Africa's research challenges necessitates robust infrastructure and sustainable funding, among other elements. Indeed, beneficiaries of capacity-building programmes have identified the lack of infrastructure as a significant impediment to research in Africa [15]. The COVID-19 pandemic has further underscored the need for well-established scientific research infrastructure on the continent [16]. We share our experience in establishing the Biomedical Science Research Centre (BioRTC) at Yobe State University in Northeast Nigeria. This initiative offers a case study of efforts to enhance Africa's research capacity amidst the region's unique challenges.

1.1. Major Challenges for Laboratory Establishment in Resource-Limited Settings

Research in Africa faces several challenges that can hinder progress in scientific and academic fields. These problems are sometimes mutually causative and prevalent in the majority of Sub-Saharan African countries. We have identified the prominent challenges and described them below. Following this, we describe the steps we followed in establishing a centre to address some of these challenges.

1.1.1. Limited funding

Most Sub-Saharan African countries spend less than 0.5% of their Gross Development Product (GDP) on research and development, less than the average expenditure of the lower-middle-income countries (0.6%) [4]. Establishing a laboratory is a financially demanding undertaking, and the inadequacy of funds presents a foremost challenge. Given the poor economic indices of African nations, governments on the continent face a shortage of financial resources to support the creation and upkeep of laboratories. As a result, the necessary funding for laboratory establishment and maintenance is often lacking.

1.1.2. Lack of scientific equipment

Insufficient research equipment is a significant impediment to research in Africa and other resource-limited settings [6]. The lack of equipment is tied to the overall lack of funding, as many African countries have limited resources to invest in research infrastructure and equipment. The cost of scientific equipment is often prohibitively expensive, making it difficult for researchers and academic institutions to acquire the necessary tools to conduct research. Paradoxically, the absence of equipment also precludes African researchers from accessing particular grants, because funders often require a demonstration of high-level skills and available infrastructure that can only be obtained when the equipment is locally available. Therefore, African researchers find themselves in a mutually contradictory quandary.

1.1.3. Lack of equipment maintenance

Regular and prompt equipment maintenance is integral to the longevity and sustainability of scientific endeavours. However, in resource-limited settings, even when scientific equipment is available, necessary maintenance services often aren't locally accessible. This forces institutions to source these services externally, usually at a high cost, resulting in inadequate maintenance and delayed repairs. Consequently, this often leads to equipment breakdowns, inaccurate results, and challenges in persuading funders to purchase similar or more sophisticated equipment in the future.

1.1.4. Limited infrastructure and access to essential services

Infrastructure limitations and restricted access to essential services present considerable challenges in resource-limited settings. In particular, the lack of fundamental amenities such as

consistent power supply and clean water forms a significant barrier to the establishment and operation of laboratories [17]. These basic necessities are essential for facilitating laboratory operations, and their unavailability in certain regions makes it arduous to build and maintain functional laboratories.

1.1.5. Lack of trained personnel

Some high-tech equipment, such as nuclear magnetic resonance spectrophotometers (NMR) and high-performance liquid chromatography (HPLC), are available in African institutions. Regrettably, the lack of competent personnel, both in operating and maintaining the equipment, often leads to machine breakdowns shortly after procurement. In one World Health Organisation report, up to 70% of medical equipment in Africa are not used efficiently due to, among other factors, a lack of trained personnel [18]. This deficit in skilled researchers, scientists, and technicians is primarily attributable to insufficient access to training programs. In numerous instances, individuals who undergo training tend to seek more lucrative opportunities abroad, contributing to the brain drain phenomenon in Africa [19]. The scarcity of trained personnel can also translate into inadequate support for research projects, which may ultimately undermine the quality of research outcomes.

1.1.6. Political instability and insecurity

The challenging landscape of political instability and insecurity in Africa has the potential to hinder the establishment and maintenance of functional laboratories. From 2020 to 2022 alone, 11 attempted coups occurred, with seven succeeding in five countries [20]. Currently, Sudan is under an intense social conflict caused by a successful overthrowing of the government. Terrorism is prevalent in most West and East African countries [21]. In such circumstances, the unfavourable environment created by these factors can prove inimical to scientific research and impede progress in scientific fields [22]. Establishing laboratories requires not only the procurement of specialised equipment and trained personnel but also a stable and secure environment that fosters innovation and scientific exploration. In many instances, political instability and insecurity can lead to the diversion of resources from scientific research, making it difficult to maintain the necessary infrastructure and funding for laboratory operations. Moreover, these conditions can obstruct the mobility of researchers, technicians, and required laboratory reagents, thereby hindering collaboration, knowledge creation, and sharing.

1.1.7. Inequality

The widespread prevalence of gender, regional, ethnic, and religious inequality in many African societies can breed mistrust and marginalisation, thereby contributing to several previously outlined challenges [3]. Uneven distribution of resources and opportunities can exacerbate disparities in access to education, health care, and other basic amenities, resulting in limited participation in scientific research and innovation by some groups. Such disparities can contribute to the underrepresentation of certain groups in the sciences and the underutilisation of their perspectives and ideas. Moreover, such social exclusion and marginalisation can create an

unfavourable environment for collaborative research, posing a significant barrier to scientific advancement.

1.2. Workable solutions

Despite these challenges, there are several pockets of resilience across the continent that have succeeded in establishing world-class research infrastructure. In an effort to create a similar solution, we have identified a set of viable solutions (Figure 1), which can be classified into four categories. Given the mutually non-exclusive nature of the challenges mentioned earlier, it is crucial to implement these solutions concurrently.

1.2.1. Resource optimisation strategies

Resource optimisation, a process that involves allocating and utilising resources efficiently to maximise benefits while minimising waste, becomes particularly critical in resource-limited settings. For institutions establishing and maintaining a laboratory under such circumstances, it is imperative to adopt a set of resource optimisation strategies (ROS) to ensure sustainability. These strategies may encompass collaboration and cost-sharing models with other institutions or organisations, prioritising essential equipment, and exploring alternative options such as procuring or purchasing refurbished equipment. Furthermore, harnessing local personnel and offering pertinent training and development opportunities can bolster local capacity, thereby reducing the dependency on costly foreign expertise. By deploying these ROS, researchers and institutions can cut costs, bolster efficiency, and enhance the longevity of laboratory operations in resource-limited settings. However, it is vital to adapt ROS to the specific circumstances of each laboratory, considering local needs, available resources, and overarching research objectives.

1.2.2. Collaboration with local partners and international organisations

Collaboration with local partners and international organisations is instrumental in sustaining a laboratory in resource-limited settings. Local partnerships foster the exchange of expertise, knowledge, and resources among community members, researchers, and institutions, building trust and support vital for the laboratory's long-term success. For instance, integrating local community members into laboratory activities and research projects can promote a sense of ownership and stimulate active participation in research. On the other hand, international collaborations offer avenues for sharing expertise, surplus supplies, and funding opportunities, boosting the laboratory's capacity and contributing to its sustainability. Collaborating with international entities helps build a robust network of experts and organisations for ongoing support and future collaborations. Moreover, such partnerships can facilitate access to specialised equipment, training, and resources not readily available locally. In essence, collaborations with both local and international partners broaden reach, enhance laboratory capacity, and foster community engagement—factors pivotal for laboratory sustainability. However, effective collaboration requires mutual respect, transparency, and shared goals. Hence, establishing clear communication channels and mechanisms for the equitable distribution of benefits and resources is fundamental.

1.2.3. Training and capacity building for personnel

Trained personnel play a crucial role in ensuring the sustainability of any laboratory. Therefore, training and capacity-building programs are critical solutions to challenges associated with establishing a laboratory in resource-limited settings. Adequately trained personnel can improve the quality of services and ensure accurate results and reliable findings. Furthermore, the increased efficiency resulting from well-trained personnel can save costs and enhance the laboratory's research capacity. Empowering local personnel through training and capacity-building programs builds trust, motivation, and a sense of ownership within the community. This engagement contributes to community outreach, which is essential for the laboratory's long-term success. Further, equipping local personnel with the necessary skills and knowledge reduces dependence on foreign experts, thereby increasing the sustainability of the local workforce. Investing in training and capacity-building programs for laboratory personnel is a crucial step towards the sustainability of the laboratory.

1.2.4. Mitigating political uncertainties and policy engagement

In resource-limited settings, engaging with stakeholders is crucial to the laboratory's success. Stakeholders include not only university officials and community leaders, but also local government and state officials. Building a broad base of support for the laboratory can help to mitigate the impact of political instability, as well as other challenges that may arise. Engaging with stakeholders can help to ensure that the laboratory is seen as a valuable asset to the community and that its contributions are recognised and supported. However, in the face of political instability, contingency plans must be put in place to ensure that the laboratory can continue to operate. This may involve measures such as backup power generators or alternative supply chains for essential equipment and supplies. Additionally, it may be necessary to establish communication channels with external partners and stakeholders in order to secure additional support or resources in the event of a crisis.

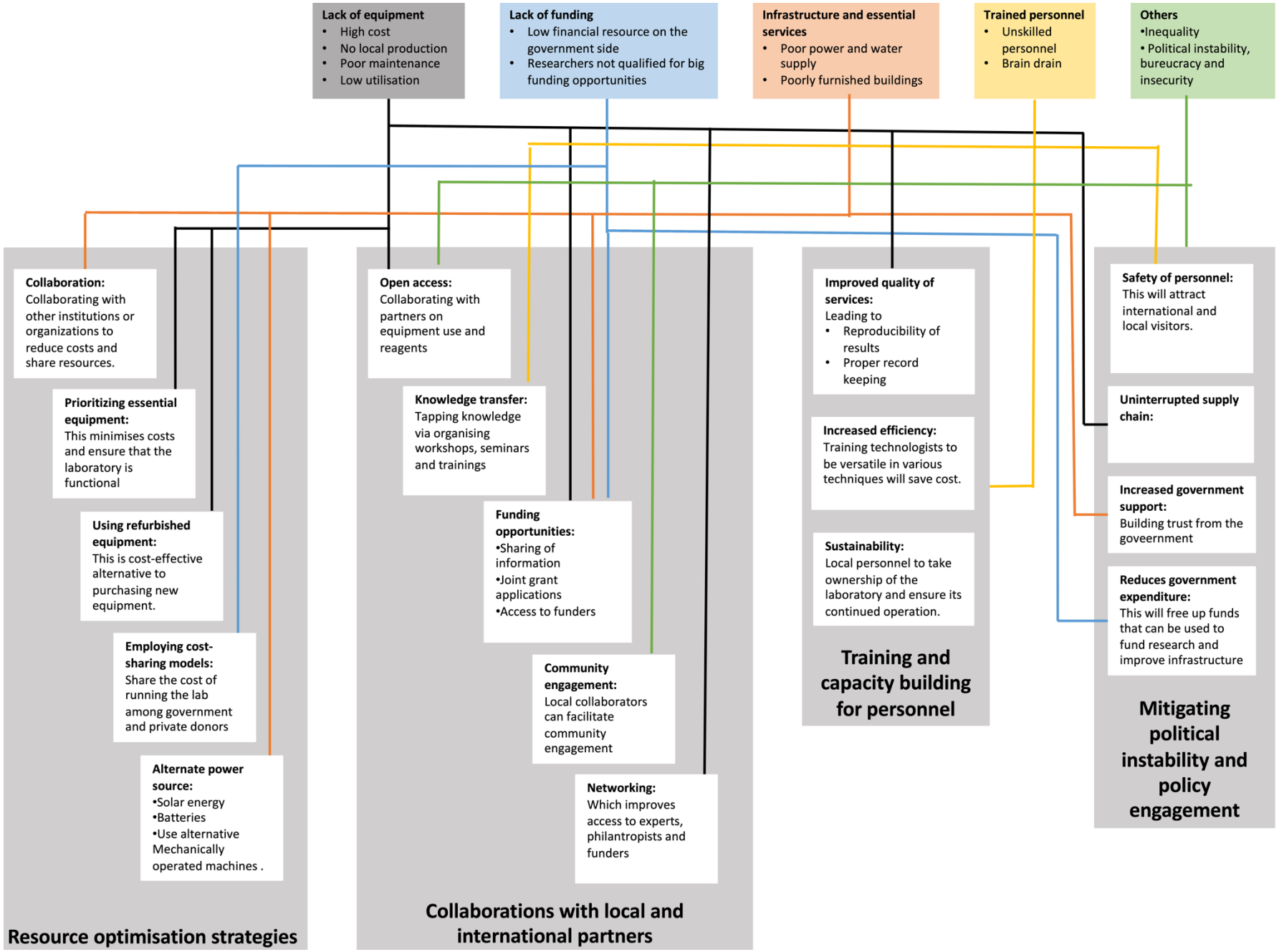


Figure 1. A schematic diagram showing the major problems of establishing a laboratory in resource-limited settings and ways to solve the problems. The five coloured boxes (black, blue, red, yellow and green) contain the list of the problems, while the corresponding-coloured lines link the problems to potential solutions.

In the subsequent sections of this article, we provide some solutions that we adopted to the problems outlined, leading to the beginning of a success story endeavouring to provide cutting-edge infrastructure and training for African biomedical scientists at minimal cost to the researchers.

2. Case Study: Establishment of the Biomedical Science Research and Training Centre (BioRTC) in Northeast Nigeria

2.1. Context of the region

Northeastern Nigeria, the second most populous region in the country, harbours a tapestry of cultural and biological diversity that offers a rich basis for innovative scientific exploration. Despite past challenges, including socio-economic hurdles and security issues that have historically impacted progress, the region is witnessing a renaissance marked by remarkable resilience and concerted efforts towards development. The Nigerian government's establishment of the North East Development Commission [12] underscores this commitment to transform the region into a thriving hub for societal progress, with specific emphasis on improving education and healthcare. Moreover, each of the six states in the region has a university owned and financed by the federal (central) government of Nigeria, as well as a state university funded by the state government, all of which offer biomedical science-related courses. Private universities in the region, including the American University of Nigeria in Adamawa state, further contribute to the university education output of the region. While the region's current biomedical research output, as reflected by the number of PUBMED-indexed documents (1723 documents), may be less compared to other regions in Nigeria (Northwest = 4671, Northcentral = 11951, Southwest = 15812, Southeast = 6844 and South-South = 14044 as of 12/03/2023), there's an opportunity for significant growth. This opportunity is particularly poignant considering the region's unique ecological and social conditions, as well as human and animal diversity [8, 9], which presents an untapped reservoir of research potential.

The BioRTC is located in Yobe State University (YSU), located in Damaturu (11.7470° N, 11.9662° E), Yobe state’s capital. In addition to the state University, Damaturu is home to the state government’s house, state house of assembly, and high court. The security structure present in Damaturu includes the Nigerian Police Force headquarters, 233 battalion of the Nigeria Army in Damaturu, the Department of State Services (DSS) and Nigeria Security and Civil Defence Corps (NSCDC) commands. Social amenities include a sports stadium and other satellite commercial sports centres and various tourist attraction spots such as old monuments like the 8000-Year-Old Dufuna Canoe, and an oasis located deep in the Sahara to the Northern part of the state (Figure 2). The state shares land borders with the Niger Republic on the North, and with four Nigerian states; the Northeastern states of Borno, Gombe, Bauchi, and Jigawa state (Northwest Nigeria), respectively, from East to West (Figure 2).

Figure 2: Map of Nigeria showing the geographical location of Yobe state (Left) and a picture of some of the 2022 BioRTC Summer School participants at the desert oasis located in Yusufari local government of Yobe state (Middle and Right).

2.2. Preliminary consultations

2.2.1. The very beginning

Seeing the challenges of scientific infrastructure in Africa, Dr Mahmoud Bukar Maina, a neuroscientist at the University of Sussex in the UK and a member of the organisation Teaching and Research in Natural Sciences for Development in Africa (TReND in Africa)[23], conceived establishing a world-leading research laboratory in neuroscience to enhance the research capabilities of Nigeria. It was envisioned to be open to all researchers and to serve as a proof of principle that with the right motivation, investment, cooperation and will, research and development can be used as powerful tools for development. In 2017 Dr Maina organised a science festival at YSU during which he officially discussed with the University's top management about his plans, to which they accepted and promised their full support. The science festival was funded by The Physiological Society UK and served the purpose of sensitising the school management on the benefit to the University, at least in terms of popularising the name of the University. In addition to regular advice from the Directors of TReND in Africa, Dr Maina further established a small team comprising of colleagues (Dr Raouf Issa and Dr Takeshi Yoshimatsu initially, and later Dr Andre Maia Chagas and Dr Renee Hartig) to support with the development of the initiative. With consultation with the team and local researchers at YSU, primarily Dr Muhammad Musa Lawan and Zaid Muhammad, as well as the top management of the YSU, BioRTC's focus on neuroscience research was broadened to increase the appeal of the centre to the University and government, since at the time of establishing the BioRTC, neuroscience as a discipline was not well established across Africa. Dr Maina selected Yobe State University because of his personal and political connection to Yobe State as an indigene, which increased the likelihood of securing support from the community and the University. BioRTC was envisaged to be a permanent centre, run equitably by local researchers which should place BioRTC in a strategic position to be a driving force for change over a long period of time, having local capacity to:

I. Train others, multiplying the reach and impact of the centre.
II. Repair and customise local equipment

III. Research on topics of interest to them and involving local issues and particularities such as local animal species that have never been studied before and understanding diseases using samples from ethnically diverse indigenous populations.

2.2.2. Identifying key stakeholders and partners

From the inception of the centre, several key stakeholders were identified, including TReND in Africa, YSU, and the Yobe State Government (YSG). The TReND in Africa network has connections in Europe that enable it to obtain used but functional equipment or refurbished equipment, access to a network of mentors both within and outside Africa, and a long-term commitment to promoting African science. YSU has the academic environment and infrastructure to house the centre, and the YSG has the funds to support the centre's day-to-day operations.

Dr Maina, a member of TReND in Africa, a staff member at the University of Sussex and YSU in a visiting capacity, as well as an indigene of Yobe State, initiated conversations with the various stakeholders independently. The equipment received by the centre from Europe is governed by a Memorandum of Understanding (MoU) signed between YSU and TReND in Africa. This MoU ensures the protection of the equipment from internal policies that may be detrimental to the centre, while enabling YSU to benefit from them.

To ensure the success of the project, the stakeholders were engaged to understand the benefits of the centre. As with other state-run universities in Nigeria, YSU receives a relatively modest annual budget from the YSG to support its activities. Therefore, it was crucial to engage the University to understand the significant benefits it would gain from hosting the centre.

2.2.3. Initial funding source

The Yobe State Government's financial support for the BioRTC, particularly in terms of staff salaries, has been instrumental in alleviating the burden of recruitment and financial management from the centre. However, the acquisition and operation of high-tech equipment such as the confocal microscope require a highly skilled postdoctoral imaging scientist, whose salary was covered by an external grant from the Chan Zuckerberg Initiative grant Dr MB Maina. The BioRTC has also received additional funding from the Wellcome Trust Neuroscience and Mental Health Team to support networking and further development of the centre. These funding sources have enabled BioRTC to attract highly qualified staff and acquire necessary equipment, ultimately enhancing the capacity and output of the centre.

2.2.4. Procurement of equipment

The equipment for the start-up of the centre was donated by various partners, with the majority secured from the University of Sussex and Crick Institute London via TReND in Africa. Dr Maina also received additional equipment through an advertised call published by the University of Sussex on the UK Times Higher Education (see the acknowledgement section). A major issue, however, was the cost of shipping the equipment to Nigeria and Yobe state, which is approximately 1,300 km away from the main seaport and around 700 km from a major international airport. Fortunately, from the outset, YSU agreed to cover the shipping costs of

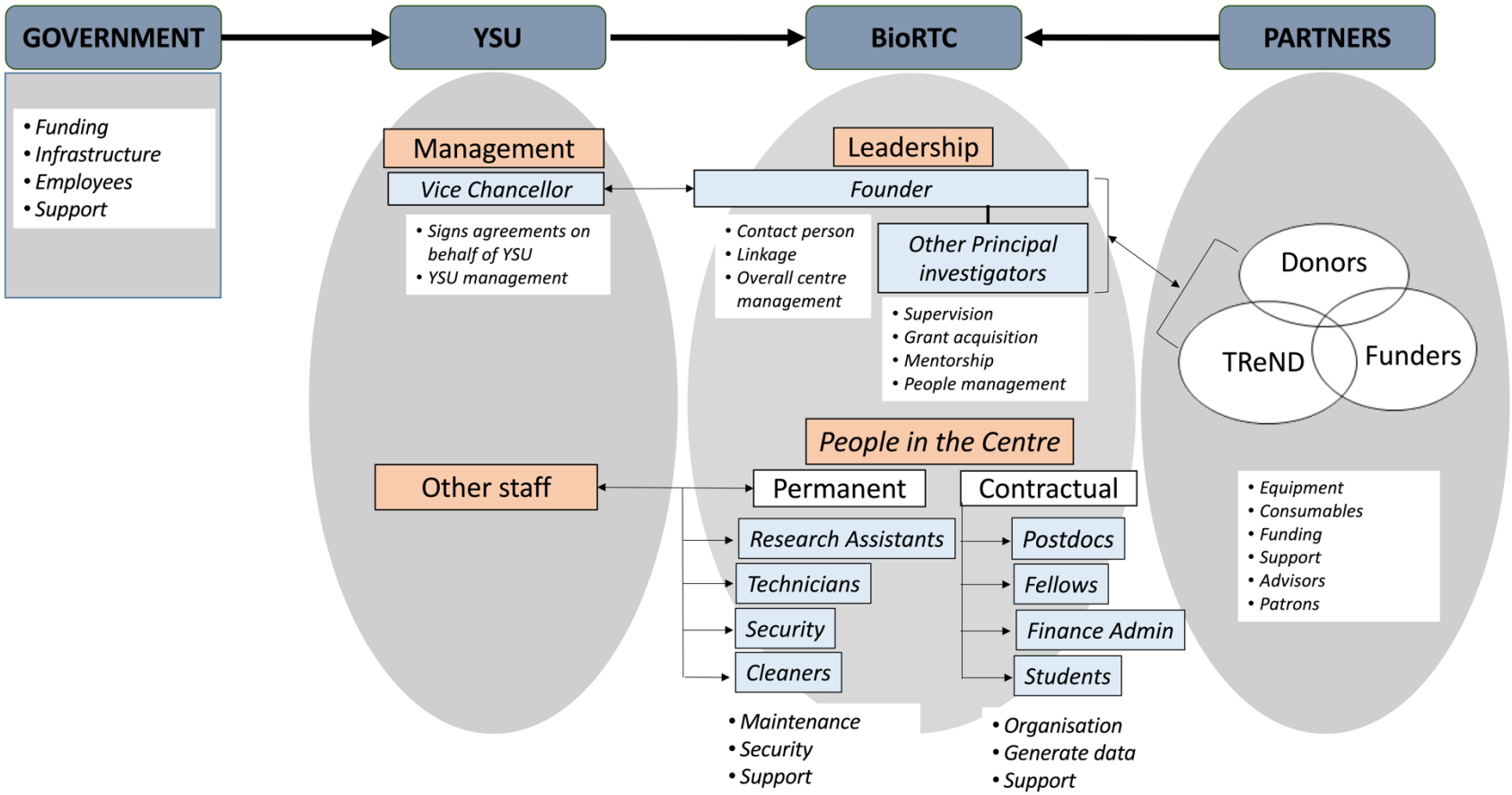
donated equipment. According to the MoU signed between TReND in Africa and YSU, all the costs of clearance, shipment, and installation of the donated equipment were to be fully covered by YSU. However, some of the specialised equipment was extremely expensive to ship and install (e.g., confocal microscope), and as a result, external grants were relied upon to complement local funding. Thus, in terms of equipping the centre, a feasible modus operandi was established, and all parties involved were satisfied.

Additionally, the founder of the centre recognized the need to obtain grants to purchase equipment that may not be available through donations. As a result, Dr Maina was able to secure grants that allowed for the purchase of equipment such as the LICOR ODYSSEY™ gel imager, as well as reagents, consumables, and glass and plastic wares. These grants enabled the centre to acquire additional equipment and resources beyond what was donated.

2.3. The current state of BioRTC

2.3.1. Organogram

Dr Maina serves as the primary contact and the Director of the centre. In this role, Dr Maina acts as the bridge between BioRTC and various stakeholders, independently initiating vital conversations and collaborations. The four founding principal investigators (PIs), who are also members of TReND in Africa and visiting staff of YSU, each have ongoing projects at the centre. They play crucial roles in supervising trainees, providing mentorship, and securing grants for their respective projects. BioRTC also has an advisory board comprising distinguished scientists worldwide, providing valuable guidance and support. The centre hosts postdoctoral researchers, research assistants, PhD and MSc students (the majority being visitors), and interns who actively engage in experimental work. Additionally, technologists and technicians maintain the laboratory equipment and reagents. Some of the centre’s research assistants serve dual roles - while they are staff of other YSU departments, they are also integral parts of the BioRTC team. To ensure the smooth running of the centre, we have a team of security personnel and cleaners employed by YSU. We also have a contractual financial officer responsible for managing the centre's financial activities. Our organisational structure is designed with adaptability in mind, accommodating the inevitable changes and challenges we will face as we work towards our ambitious goals.



365

366 **Figure 3: The current organogram for BioRTC.** The Founder and Director serve as the link between donors and the government
367 through the Yobe State University school management. Together with other principal investigators, he maintains active research within
368 the centre and coordinates the activities of the centre.

2.3.2. Infrastructure and equipment

The centre has taken off in its temporary site at the College of Medical Sciences, YSU, Damaturu. The space allocated to the centre comprises 134m2 divided into two laboratories and four rooms. With a commitment from the state government, the centre is expected to move to its own dedicated building by 2024. This new space will comprise 512 m2 divided into 8 rooms, including 5 laboratories, 3 offices, and a seminar room (Figure 4). The centre is powered by the national grid and a 2.5-horsepower generator of the college on working days. In addition, solar-charged batteries provide 7.5 kVa of electricity to ensure uninterrupted power supply to essential equipment. This backup power supply is essential in Nigeria, where power outages are common. The centre has air conditioning systems in all the laboratories and rooms. The centre has many important high-tech equipment including the first laser scanning confocal microscope in Nigeria (Zeiss LSM 700, donated by The Crick Institute UK), a LI-COR ODYSSEY XF gel reader, real-time PCR machines, conventional PCR machines, and equipment for the tissue culture facility. The full list of equipment and resources available at the centre can be accessed via the BioRTC website, which is regularly updated (www.biortc.com/equipment/). A large number of chemicals and consumables, including various molecular biology enzymes and kits, were donated by Promega UK through TReND in Africa.

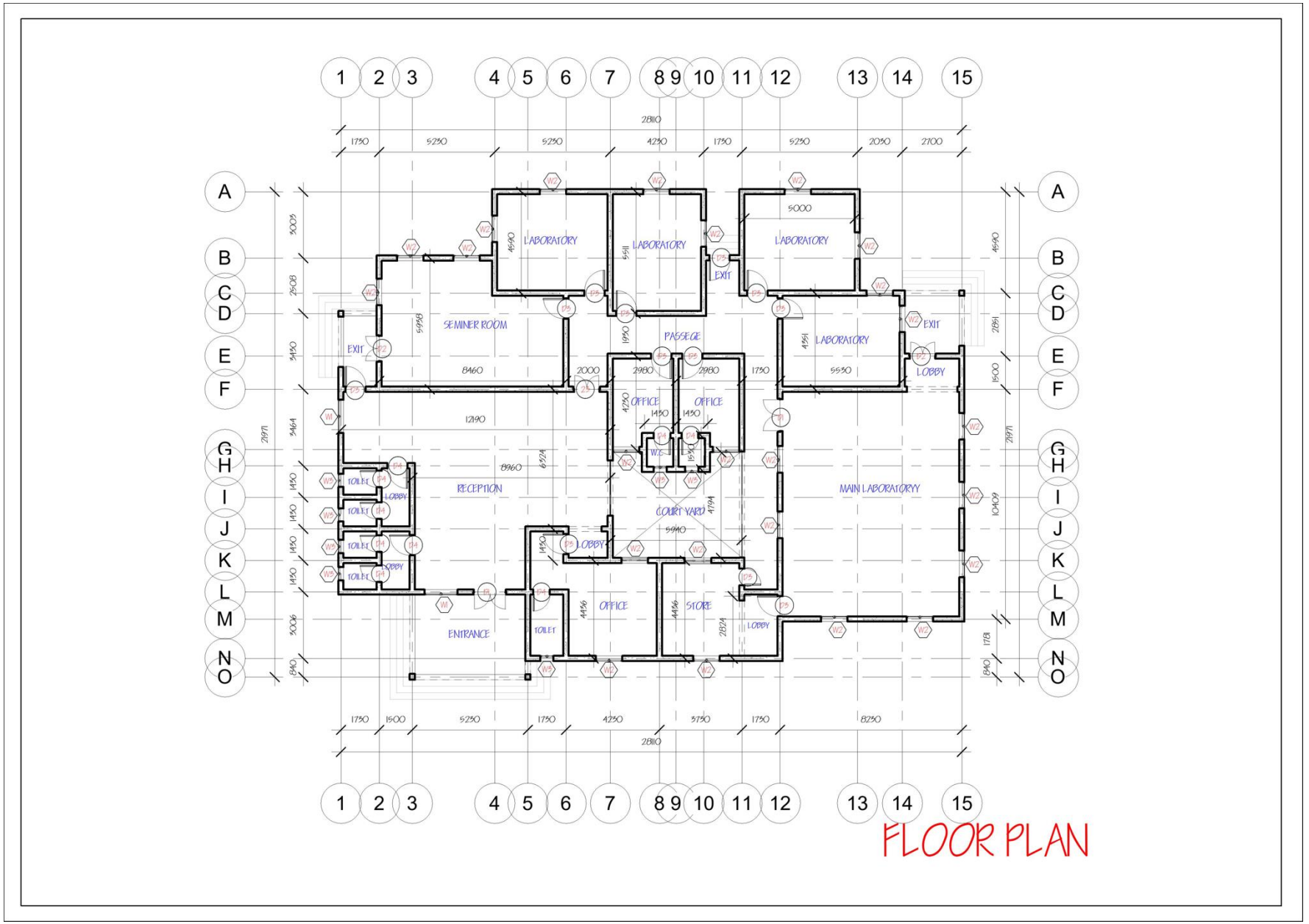


Figure 4: Floor Plan of BioRTC's new site. BioRTC is expected to move to its new permanent site in 2024, which will be constructed based on this floor plan.

2.3.3. Advisors

BioRTC has an advisory board composed of veteran researchers from across the globe (https://biortc.com/advisory-board/). They have thus far provided guidance and advice on the activities of the centre and provided research and networking opportunities.

2.3.4. Research

The sustainability of the centre and longevity of the equipment rely on the continuous usage of the available equipment, and research is at the core of achieving these goals. Research at BioRTC is currently conducted using two models. The first model is PI-led research, where each of the PIs at the centre independently runs research in collaboration with local researchers, funded by research grants obtained by the PIs (https://biortc.com/research/). This model achieves several purposes, including ensuring the utilisation of the equipment at the centre and demonstrating the equipment's utility to local researchers who may not be familiar with its use in their research.

The second model involves visiting researchers who come to conduct their own research. As an open-access facility, the equipment at the centre is available to all scientists who wish to use it. However, a set of regulations, including a laboratory visit application (available at https://biortc.com/lab-visit-application/), preliminary training and familiarisation with predefined rules and regulations, and an affordable access fee (for equipment that require maintenance), is a prerequisite to accessing the facility.

2.3.5. Workshops

The centre organises various workshops to fulfil one of the core aims of BioRTC, i.e., the training of African scientists. So far, four of these workshops targeting various demographics have been organised (Table 1). So far, all the six geopolitical regions of Nigeria had participants in these workshops and the selection process gave due consideration to gender balance. The planning of the workshops and their resulting success is one of the key demonstrations of a successful implementation of a robust stakeholder outreach recorded by the BioRTC. In all the workshops, the participants were offered free accommodation, and each of the stakeholders (TReND, YSG and YSU) contributed immensely to the success of the workshops. Due to the security challenges experienced in the early 2010s, the guaranteed security accorded to the workshop participants by the state government was instrumental in the seamless arrival and stay of the facilitators and the participants throughout the workshop period. There are plans to organise workshops twice a year, with one of these being a summer school.

Table 1: Summary of the workshops conducted by BioRTC

Workshop title	Year	No of Facilitators (international)	Target participants	No of participants	Duration
Bioimaging, Open Hardware, and Neuroscience Research	2022	8(5)	Postgraduate students and established researchers	46	2 weeks
Data analysis for healthcare professionals	2022	10(7)	Clinicians and healthcare professionals from across Northeast Nigeria	30	1 week
Workshop on Confocal microscopy	2023	4(3)	Postgraduate students and early career researchers	20	1 week

2.3.6. Training and local capacity building

Understanding the critical importance of skill enhancement and capacity building for the laboratory's long-term sustainability, BioRTC has made these aspects core priorities. All members of the centre's staff are encouraged to pursue opportunities for continuous learning and professional development. This emphasis on growth and development has led to the establishment of several critical partnerships. BioRTC has established collaborative links with the University of Sussex Neuroscience Centre and the Imaging and Cytometry facility at the University of York, facilitating opportunities for staff to learn directly from these world-class institutions. Three local staff members, including a technologist, were sponsored to visit these centres, acquiring valuable skills and knowledge in managing a high-tech laboratory. Moroever, BioRTC is developing further training opportunities and knowledge exchange through links with the Advanced Imaging Centre Janelia (USA), TReND in Africa, the African Bioimaging Consortium, and Global Bioimaging. One key benefit of these partnerships is the specialised training opportunities that arise. For example, a staff member had the chance to study the retina of local reptilian species during a visit, directly aligning with BioRTC's research interests in understanding the unique biodiversity of Northeast Nigeria. Additionally, these collaborations have tangible benefits for the centre's facilities. A recent visit to the Imaging and Cytometry facility

at the University of York led to the generous donation of a Zeiss LSM 780 confocal microscope, further enhancing BioRTC's imaging capabilities.

2.3.7. Collaboration with local partners and international organisations

BioRTC has embarked on the significant task of establishing robust research collaborations with several leading academic institutions across Nigeria, such as Ahmadu Bello University Zaria, University of Maiduguri, Umaru Musa Yar'adua University Katsina, and Yobe State University Teaching Hospital Damaturu. This nascent alliance aims to not only advance the centre's research objectives but also to optimise the utilisation of the state-of-the-art research facilities at BioRTC. Furthermore, the envisioned research partnerships will foster shared knowledge, expertise, and resources, forming the foundation for the future advancement of biomedical research in Nigeria. BioRTC's aspiration is to elevate research standards in Nigeria by sharing its cutting-edge resources and expertise with the broader academic community, fostering fresh avenues for collaboration and innovation. The intended strategic collaborations are designed to be mutually beneficial, as it will provide non-BioRTC researchers access to BioRTC's advanced equipment, resources, and skilled staff, while also helping the centre achieve its objectives of training and capacity building in African sciences. These budding research partnerships underscore BioRTC's commitment to promoting long-term collaborations in research and development across Nigeria and the African continent.

2.3.8. Community outreach

Community outreach forms an integral part of BioRTC's sustainability strategy, ever since its inception. These early initiatives included laboratory open afternoons, inviting non-scientists to gain insight into the centre's work, as well as visits and engagements with local and traditional community leaders, policymakers, government officials, and school students. These programmes aimed to elucidate the centre's objectives, thus fostering transparency and facilitating a broader understanding and appreciation of science within the community. Furthermore, the engagement with policymakers and government officials enabled BioRTC to align its activities with national priorities, ensuring mutual growth. This commitment to community outreach continues to serve multiple purposes, such as inspiring future scientists, bridging the gap between scientific research and society, and strengthening alliances with local stakeholders. All these activities contribute significantly to the centre's long-term viability and success.

2.3.9. Plan for sustainability and the role of Open Science

BioRTC is dedicated to ensuring the long-term sustainability of the research centre and its resources, particularly given the financial and infrastructural challenges in Africa. The promotion of open resources and open science forms the core of our strategy. This strategy allows researchers from all over the world to use the available facilities and equipment. This not only promotes collaboration but also ensures that the available equipment is fully utilised. Researchers are also required to undergo preliminary training and familiarisation with the rules and regulations of the centre to ensure proper and safe use of the equipment. This approach also maximises the usage of our equipment while enhancing the visibility and impact of the research conducted.

Moreover, the centre promotes open data sharing and open science. Researchers are encouraged to share their data and research findings openly, which increases the visibility and impact of the research.

To further guarantee the sustainability and functionality of our equipment, we provide training in open science during our summer schools and workshops. This includes teaching local researchers about equipment repair using 3D printing technology. We have invested in tools for basic equipment repair and have staff members dedicated to this essential maintenance task. With the support of YSG, BioRTC staff have been sponsored to visit the University of Sussex Neuroscience Centre to acquire advanced open science skills in equipment maintenance, repair and upcycling. These staff form part of the core local personnel to train other members of our centre, helping to develop a self-sustaining cycle of skill acquisition and transfer.

In summary, our sustainability strategy encompasses the following key points:

1. Continuously attract funding.
2. Open access use of all equipment in the centre by African scientists who will be required to bring consumables and pay an affordable equipment maintenance fee
3. Incorporate biomedical engineering in our staff training, allowing minor equipment repairs to be performed in-house.
4. Identify and establish partnerships with local suppliers to reduce procurement costs.
5. Maintain continuous engagement with the government to advocate for scientific research support and align our activities with their priorities.
6. Continue building partnerships with international scientific communities and organisations to secure access to additional resources and expertise.
7. Foster a strong research collaboration network within Nigeria to share resources and expertise, and to increase the centre's visibility and credibility.
8. Encourage scientific entrepreneurship among staff and researchers to explore potential commercialisation of research outcomes.
9. Strengthen community outreach programs to build local support and inspire future scientists in the region.
10. Develop an alumni network of former staff and students to maintain relationships and potential future collaborations.
11. Establish a mentoring system within the centre to promote staff development and retention.
12. Incorporate regular equipment auditing and preventive maintenance schedules to extend the life and performance of the lab equipment.
13. Build capacity in grant writing among the staff to increase chances of securing research funding
14. Regularly review and update strategic plans to respond to changing circumstances and needs.

3. Conclusion

Establishing a high-tech research laboratory in resource-limited settings is a formidable task, but with meticulous planning, it is achievable. We have demonstrated this by setting up BioRTC in Northeast Nigeria, a region that embodies the challenges faced by many African countries. We have identified several key factors that should be considered before and after establishing such a laboratory. One of the most critical factors is identifying the appropriate stakeholders and engaging with the community and policymakers during the early stages of the establishment. This helps to build a supportive network that can provide both financial and logistical assistance. Equally important is securing a reliable source of funding, ensuring the existence of adequate infrastructure or ways to source the infrastructure, and a clear plan for sustainability. To ensure the sustainability of the centre, we have identified key factors necessary. These include resource optimisation strategies, international and local collaborations, training of local personnel, and mitigating uncertainties. These strategies are crucial for long-term sustainability and the successful implementation of research projects. We are in the early stages of our journey, growing and learning as we navigate the challenges and opportunities of our setting. As such, we welcome the support and collaboration of those who share our vision and believe in our potential. We share our experience and insights with the hope that they may guide other researchers from the most disadvantaged regions of Africa and other resource-limited settings in establishing their own research laboratories. We are learning that, with a strategic approach and unwavering commitment, it is possible to establish and sustain research laboratories of a high standard that can contribute significantly to their communities, even in challenging environments.

Acknowledgements

Our heartfelt gratitude to all the Yobe State Government and Yobe State University staff, whose contributions, though too numerous to list individually, have been invaluable. We are particularly indebted to His Excellency Hon. Mai Mala Buni (CON), the Governor of Yobe State, for his unwavering support and endorsement of BioRTC. We also express our profound thanks to the Secretary to the Yobe State Government, Baba Malum Wali (mni), who provided essential support by engaging with the Governor and other stakeholders in favour of BioRTC. We would also like to acknowledge the Vice-Chancellor of the University – Prof. Mala Daura, and the Registrar of the Yobe State University – Dr Kalli Alkali Gazali, for their remarkable contributions, serving as the vital link between BioRTC and Yobe State Government through the SSG. We owe gratitude to TReND in Africa, whose support served as the nucleus for the formation of BioRTC and who continues to back our efforts. We are grateful for funding from the Yobe State Government, the Chan Zuckerberg Initiative, The Wellcome Trust Neuroscience and Mental Health team and The Company of Biologists. We also appreciate Global Bioimaging, which supported BioRTC staff training in the UK. Our gratitude extends to various groups at the University of Sussex for donating equipment to BioRTC and several members of the University of Sussex community. We appreciate the Crick Institute London, the Imaging and Cytometry facility at the University of York, the HSE Science and Research Centre (Buxton, UK), Corning, Star Labs, and LUMICKS (Amsterdam) for donating equipment to BioRTC. We also wish to thank those donors who preferred to remain anonymous. Finally, we are thankful for the support and advice from our advisory boards and personnel at numerous research centres worldwide.

References

1. AfDB, A., *African Development Report 2015-Growth, Poverty and Inequality Nexus: Overcoming Barriers to Sustainable Development*. 2016, African Development Bank.
2. Koon, A.D., et al., *Embedding health policy and systems research into decision-making processes in low-and middle-income countries.* Health research policy and systems, 2013. **11**: p. 1-9.
3. Marincola, E. and T. Kariuki, *Quality research in Africa and why it is important*. 2020, ACS Publications. p. 24155-24157.
4. World-Bank, *GDP (current US$) - Sub-Saharan Africa, World Bank Open Data*. 2023.
5. Ali, W. and A. Elbadawy, *Research output of the top 10 African countries: An analytical study.* COLLNET Journal of Scientometrics and Information Management, 2021. **15**(1): p. 9-25.
6. Maina, M.B., et al., *Two decades of neuroscience publication trends in Africa.* Nature Communications, 2021. **12**(1): p. 3429.
7. Maina, M.B., et al., *African neuroscience on the global stage: Nigeria as a model.* Eur J Neurosci, 2019.
8. CBD, *NIGERIA: FIFTH NATIONAL BIODIVERSITY REPORT*. 2015, The Convention on Biological Diversity: Online.
9. Bird, N., et al., *Dense sampling of ethnic groups within African countries reveals fine-scale genetic structure and extensive historical admixture.* Science Advances, 2023. **9**(13): p. eabq2616.
10. Abiama, E.E., C.M. Ifeagwazi, and J.C. Chukwuorji, *Rates of Occurrence and Influence of Trauma Exposure on Posttraumatic Stress Disorder Symptoms Among Survivors of Terrorist Attacks in Northeast Nigeria.* International Journal of Mental Health and Addiction, 2022. **20**(4): p. 2478-2492.
11. Kaiser, B.N., et al., *Mental health and psychosocial support needs among people displaced by Boko Haram in Nigeria.* Glob Public Health, 2020. **15**(3): p. 358-371.
12. Nyako, A., *Northeast Development Commission.* A concept note on North East Development Commission: An Institutional Framework for a sustainable solution to the Northeast National Security Challenges: Adamawa Central, Adamawa State, 2015: p. 1-22.
13. WHO, *Health researchers (in full-time equivalent) per million inhabitants, by income group (second set of charts)*. 2023, World Health Organisation.
14. Uthman, O.A., et al., *Increasing the value of health research in the WHO African Region beyond 2015—reflecting on the past, celebrating the present and building the future: a bibliometric analysis.* BMJ open, 2015. **5**(3): p. e006340.
15. Kariuki, T., et al., *Research and capacity building for control of neglected tropical diseases: the need for a different approach.* PLoS neglected tropical diseases, 2011. **5**(5): p. e1020.
16. Egyir, B., N. Obeng-Nkrumah, and G.B. Kyei, *COVID-19 pandemic and antimicrobial resistance: another call to strengthen laboratory diagnostic capacity in Africa.* African journal of laboratory medicine, 2020. **9**(1): p. 1-4.
17. Bezuidenhout, L., *Africa, Laboratory equipment and COVID-19 response.* Somatosphere, 2020.
18. WHO, *Medical device donations: considerations for solicitation and provision.* 2011.
19. Kasprowicz, V.O., et al., *African-led health research and capacity building-is it working?* BMC Public Health, 2020. **20**: p. 1-10.
20. Chin, J.J. and J. Kirkpatrick, *African coups in the COVID-19 era: A current history.* Frontiers in Political Science, 2023. **5**: p. 1077945.
21. James, N., et al., *Geometric persistence and distributional trends in worldwide terrorism.* Chaos, Solitons & Fractals, 2023. **169**: p. 113277.

22. Cohen, N. and T. Arieli, *Field research in conflict environments: Methodological challenges and snowball sampling.* Journal of peace research, 2011. **48**(4): p. 423-435.
23. Baden, T., et al., *TReND in Africa: Toward a Truly Global (Neuro)science Community.* Neuron, 2020.