

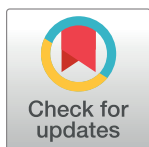
PERSPECTIVE

Think: Theory for Africa

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OPEN ACCESS

Citation: Currin CB, Khoza PN, Antrobus AD, Latham PE, Vogels TP, Raimondo JV (2019) Think: Theory for Africa. *PLoS Comput Biol* 15(7): e1007049. <https://doi.org/10.1371/journal.pcbi.1007049>

Editor: Leyla Isik, MIT, UNITED STATES

Published: July 11, 2019

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Funding: The IBRO SIMONS Computational Neuroscience Imbizo is funded by grants from the Simons Foundation, the International Brain Research Organisation (IBRO) and the Wellcome Trust. A seed event in 2015 was funded by a Royal Society-SA NRF South Africa-UK Scientific Seminar Scheme. CBC is supported by a German Academic Exchange Service (DAAD)/National Research Foundation (NRF) Joint In-Country Doctoral Scholarship and the University of Cape Town (UCT) Doctoral Research Scholarship, ADA is supported by the Gatsby Charitable Foundation, PEL is funded by the Gatsby Charitable Foundation and the Wellcome Trust (110114/Z/15/Z), TPV is funded by a Sir Henry Dale Wellcome Trust Research Fellowship WT100000 and a Wellcome Trust Senior Research Fellowship 214316/Z/18/Z. JVR is

Understanding the brain is one of the most challenging scientific problems faced by humanity. In addition to offering an improved understanding of who we are, deciphering how our brains operate will provide payoffs for the treatment of mental and neurological disease as well as the creation of intelligent systems. Consequently, developed countries are pouring ever-increasing research funds into brain science. Prominent examples include the BRAIN initiative in the United States and the Human Brain Project in Europe. Although Africa may not yet possess financial and technological resources on this scale, Africans represent a vast and growing human resource poised to make important contributions to neuroscience. As the third yearly International Brain Research Organisation (IBRO)-Simons Computational Neuroscience Imbizo recently wrapped up in South Africa, we call for greater efforts to empower Africans to join the global neuroscience community and argue that the subfield of computational neuroscience is the ideal vehicle to do so.

Computational and theoretical neuroscience, also known as neurotheory, or just “theory” within neurobiology, is a young, rapidly expanding field within neuroscience; its goal is to determine and articulate the general principles by which nervous systems perform their computations. We think it is a good example of how theory, as a subfield, can serve as a catalyst to accelerate the development of science in Africa.

Due to the diversity of methods required for understanding the brain at multiple levels [1], skills are leveraged from a range of fields, such as biology, computer science, electrical engineering, mathematics, physics, and psychology. Beyond just increasing our body of scientific knowledge, the impact of this interdisciplinary field is already significant to the clinic and industry: decoding algorithms are helping restore movement in paralyzed patients [2,3], and machine learning is continually influenced by engagement with neuroscience [4]. A notable aspect of this growing field is its accessibility: computational neuroscience requires only data and individual expertise, independent of geographic location.

There is growing momentum for experimentalists to make their data available for public access and for increased collaboration between groups, a movement led by flagship projects that curate, systematize, and make freely available large-scale neuronal data [5–8]. A parallel development has been the recent surge in open-access publishing and the establishment of alternative methods for accessing scientific papers outside of well-endowed institutions (e.g., ResearchGate, bioRxiv, and especially important in Africa, SciHub). These dual developments mean that aspiring African scientists in resource-limited settings have increasing access to the latest in both data and theory from across the broad field of neuroscience. From an African

supported by the SA NRF, SA MRC, Wellcome Trust and the FLAIR Fellowship Programme (FLR \R1\190829): a partnership between the African Academy of Sciences and the Royal Society funded by the UK Government's Global Challenges Research Fund. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: I have read the journal's policy and have the following conflicts: The authors are organisers or past students of the IBRO-Simons Computational Neuroscience Imbizo.

perspective, the subspecialty best placed to leverage these developments is computational neuroscience.

The limiting factor for computational neuroscience development in Africa (and anywhere in the world) is quantitative training. Although Africa does not currently contribute a considerable fraction of global neuroscience output (see Fig 1), education in the traditional quantitative disciplines of mathematics, physics, and biology is increasing. African researchers and collaborators are progressively initiating strategies to develop and grow neuroscience expertise through national [9,10], research-domain [11], and education and/or outreach programs [12]. Research-level capacity in quantitative disciplines is being enhanced throughout Africa by initiatives such as the African Institute for Mathematical Science (AIMS), Square Kilometer Array (SKA) [13], the Human Hereditary & Health in Africa (H3Africa) [14], and more neuroscience-focused training organisations such as TReND in Africa and the IBRO. Hallmark features of these initiatives are the integration of local and international expertise as well as sharing of resources. We note also that the confluence of genomics and neuroscience has rich potential for generating unique insights and increasing African capacity in neuroscience [15]. This burgeoning emphasis on quantitative skills development, combined with improved access to data and theory, means that now is the time to put greater effort into facilitating the involvement of Africans in computational neuroscience.

Several promising educational initiatives have recently emerged for Africa. These include annual schools in computational neuroscience (IBRO-Simons Computational Neuroscience Imbizo, isiCNI, almost 100 students trained to date) and machine learning (Deep Learning Indaba, DL Indaba, nearly 1,000 attendees), which both started in 2017. These initiatives bring young, predominantly African scientists together with leading international experts in their field. It is the relationships between students, and particularly between students and faculty, that will support the careers of these fledgling, African computational neuroscientists and machine learning practitioners.

Entering the field of computational neuroscience can be a daunting prospect; there are a proliferation of online courses, numerous textbooks, diverse conferences, and several summer schools. In addition, mailing lists and social media have become an integral component for engaging with current discussions in the field, connecting with authors, and sharing opportunities and information. Although the type of quantitative training background can inform a focus in the field, there are valuable general principles to be gained from the resources in Table 1, especially for those unsure of where to start. Lastly, although research in computational neuroscience is significantly less expensive than experimental neuroscience, there is still some cost involved, mostly for computing resources. Fortunately, many universities in Africa do have high performance computing clusters, and there is the freely available Neuroscience Gateway [16], which offers computational neuroscience-specific computing resources.

Thus far, the major strides in computational neuroscience development in Africa have come from foreign sources. To retain these initiatives and benefit from these pilot projects, African governments and academic institutions must also be willing to support projects, both financially and logistically. In addition to increasing focus on the field for African scientists, we provide several recommendations for the global computational neuroscience community to enhance the field in Africa:

1. Make funding available for Africans to attend international computational neuroscience conferences, workshops, and summer schools by providing cheaper (or free) registration and travel grants.
2. Support or organise computational neuroscience schools and workshops in Africa.

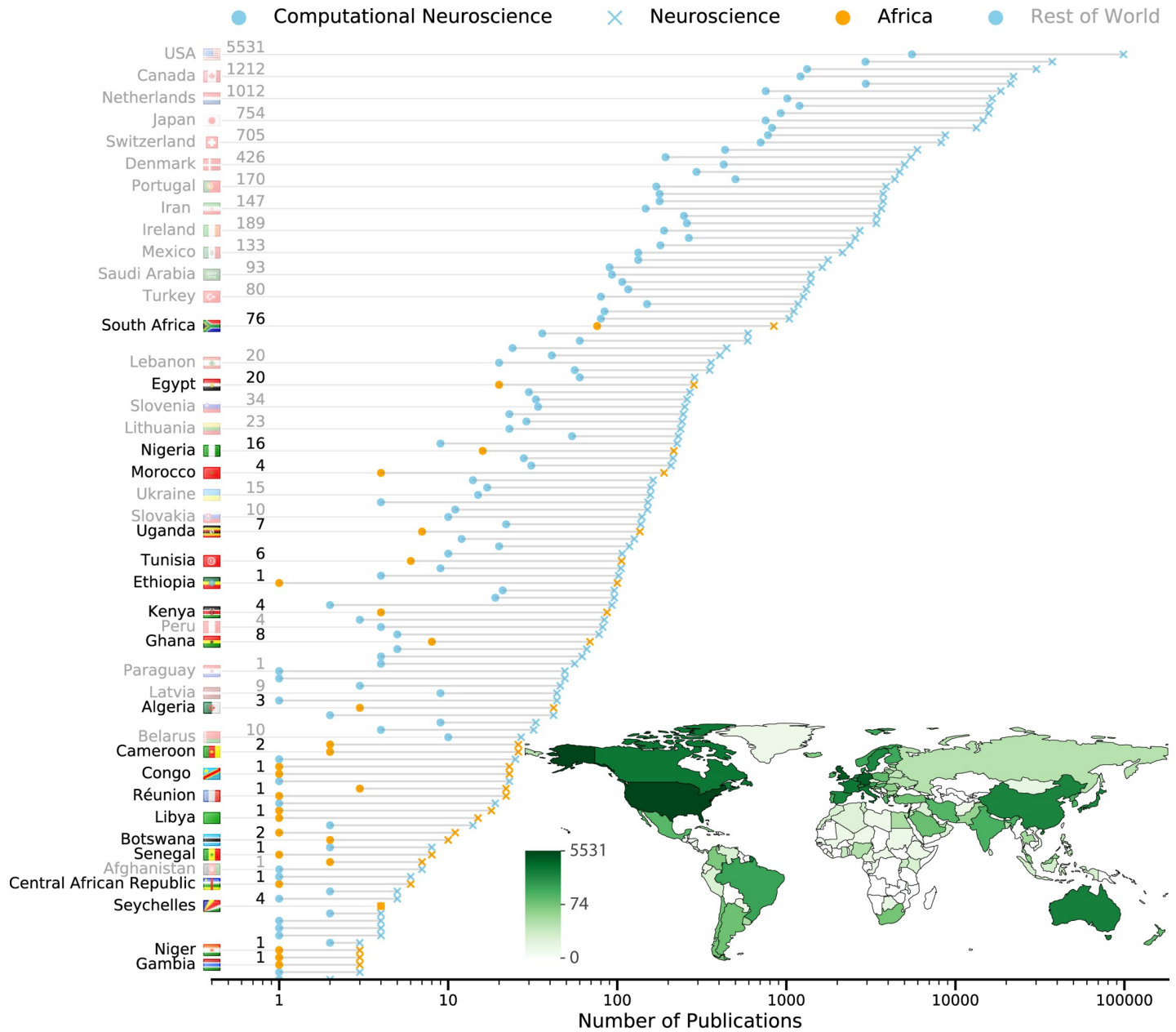


Fig 1. African contributions to neuroscience and computational neuroscience research. Countries are ranked according to the number of neuroscience publications (crosses) generated and indexed on PubMed. The number of computational neuroscience publications produced by each country are indicated by circles. Most contributing African countries (orange, black text) and a subset of global countries (blue, grey text) are labelled on the left. Some African countries (e.g., Ethiopia) have little-to-no computational neuroscience output despite notable neuroscience output. These countries have the potential to leverage existing neuroscience infrastructures for developing computational neuroscience expertise. (Inset) A world map of computational neuroscience publications produced per country, represented as a heat map, highlights the disparity between African nations and the rest of the world. The data were collected through structured searches on PubMed for authors who have been involved in a computational, mathematical, or theoretical neuroscience paper. The code used to generate the figure is available online at https://github.com/ChrisCurrin/comp_neuro_count_countries.

<https://doi.org/10.1371/journal.pcbi.1007049.g001>

3. Provide exchange opportunities for students to visit world-class research labs, and, on the other side of the exchange, bring foreign researchers to experience and enhance an African research environment.

Table 1. Quickstart guide to computational neuroscience.

Online courses	Computational Neuroscience (Coursera)	Simulation Neuroscience (edX)	Encyclopedia: Computational neuroscience (Scholarpedia)
Textbooks	Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems by Peter Dayan and Laurence F. Abbott	Information Theory, Inference and Learning Algorithms by David J. C. MacKay	Neuronal Dynamics: From single neurons to networks and models of cognition by Wulfram Gerstner, Werner M. Kistler, Richard Naud, and Liam Paninski
Schools	IBRO-Simons Computational Neuroscience Imbizo Cape Town, South Africa	Deep Learning Indaba, Africa , (Location changes annually)	Methods in Computational Neuroscience , Woods Hole, US
Conferences	Computational and Systems Neuroscience (COSYNE)	Neural Coding, Computation and Dynamics (NCCD)	Bernstein Conference
Mailing Lists	Comp-Neuro	Connectionists	Machine Learning and Data Science Africa

<https://doi.org/10.1371/journal.pcbi.1007049.t001>

4. Make available and accessible teaching material and computational resources.
5. Collaborate with African theoretical and experimental researchers.
6. Incorporate computational neuroscience research groups into African academic institutions.

In the century of the brain, African scientists and educators are poised to make important contributions to global neuroscience research. We believe that theoretical sciences, and specifically computational and theoretical neuroscience are the ideal discipline for the African continent.

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