A Natural Scientist's Perspective on the use of Artemisinin for Malaria Control

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Artemisinin is an excellent case study for observing and understanding the evolution of a folk medicine into a commercialised product. Moreover, it offers profound insight into the licensing, manufacturing, and distribution of medication needed to treat many of the world's most impoverished people. By exploring the trajectory of this well-known therapeutic, the interplay of key actors for malaria control such as the Chinese state, early entry pharmaceutical companies, and the World Health Organization (WHO) is described. What this analysis reveals is a complex entanglement of philanthropy, market trends, and governance oversights that shed light on some of the darker aspects of Artemisinin Combination Therapy (ACT) commercialisation. Additionally, particular attention is given to the absence of Indigenous communities in decision making around global malaria control efforts. This is a call to scientists in STEM fields to innovate more critically, particularly in academic spaces for the purposes of drug discovery.

The Discovery of Artemisinin

The use of plants for medicinal purposes has been implicated in pre-human populations as far back as 60, 000 years ago (Gossell-Williams et al., 2006; Hardy, 2020). Ancient medicinal writings have been associated with Egyptian, Chinese, Greek, and Arab civilisations, among several others (Gossell-Williams et al., 2006). Naturally, this co-exists with the emergence and persistence of disease. Malaria is a classic example of a highly transmissible, sometimes fatal illness that has ravaged the world for centuries (Arrow et al., 2004; Kitua & Malebo, 2004; Tu, 2011, 2017). Ancient Mesopotamian clay tablets allude to lethal periodic fevers and Egyptian remains from 5,500 years ago have been found containing malaria antigen (Arrow et al., 2004). Quinine, extracted from the bark of the Amazonian plant *Cinchona succiruba,* was one of the earliest and most widespread treatments for malaria dating back to the early 1600s; although, its use by Indigenous populations far predates that (Achan et al., 2011; Aginam, 2002). In the European world, its discovery has been credited as the first successful use of a chemical compound for infectious disease treatment (Achan et al., 2011). The ground bark of *C. succiruba* was eventually replaced by pure quinine, which was extracted and isolated in 1820 (Achan et al., 2011). This led to the extraction of subsequent cinchona derived alkaloids for malaria treatment such as quinidine, cinchonine, and cinchonidine (Achan et al., 2011). Unfortunately, just over 100 years later, malaria began to resurge as *Plasmodium falciparum* (the transmitting parasite) developed resistance to these treatments (Tu, 2011). This prompted a global taskforce of

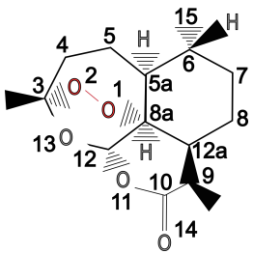

Figure 1. Molecular structure of artemisinin. The endoperoxide bridge is outlined in red.

scientists to seek alternatives, leading to the rediscovery of qinghao[1] (*Artemisia* sp.), a weedy herb native to China (Tu, 2011). An approximately 2,300 year old Chinese medicinal text by Hong Ge (*A Handbook of Prescriptions for Emergencies*) has often been credited as the source material for *A. annua's* rediscovery, but as Nobel prize winner Tu Youyou[2] describes it, this text actually elucidated the mechanism for medicinal compound extraction (Tu, 2011). In 1972, qinghaosu[3], globally known as artemisinin, was isolated from *Artemisia* sp. as a next-generation malaria treatment (Tu, 2011). The endoperoxide bridge (C-O-O-C) is the most potent aspect of artemisinin's antimalarial activity, as free iron released during parasitic infection cleaves this bridge and frees oxyradicals that disrupt *Plasmodium* cellular processes and components (Antoine et al., 2014) (Fig. 1). Pharmaceutical production of artemisinin is now exclusively sourced from *Artemisia annua* due to its higher accumulation of this compound in comparison to other *Artemisia* species (Tu, 2011). Today, artemisinin, and its highly effective derivatives for use in artemisinin combination therapies (ACT) are globally recognised and since 2005 (Tu, 2011) are referred by the World Health Organization (WHO) as a front-line treatment against malaria (Antoine et al., 2014; Furiasse, 2025; Le Menach & Anderson, 2025; Orsi et al., 2018; Paddon & Keasling, 2014).

How Commercialisation and Malaria Prevention Infrastructure Shape Availability and Access to Artemisinin Combination Therapy

Artemisinin is an excellent case study for observing and understanding the evolution of a folk medicine into a commercialised product. Moreover, it offers profound insight into the licensing,

[1] English phonetic approximation: "ching how" meaning "green herb" (Sadiq et al., 2014)
[2] The Chinese naming convention is used here: the surname is given first followed by the first name.
[3] English phonetic approximation: "ching how soo". *Su* means "basic element" in Chinese

manufacturing, and distribution of medication needed to treat many of the world's most impoverished people.

Prior to 1985, the People's Republic of China did not possess a Western capitalist patent system (Benkay, 1985). Rather, invention and innovation was predicated on obligation, service, and personal and communal satisfaction (Benkay, 1985). Thus, when Tu Youyou and her group were awarded a National Invention Certificate in 1979 for their artemisinin discovery, the right to invention would have been awarded to the state (Benkay, 1985; Tu, 2011). An inventor in this case was given a one-time payment in honour of their discovery (Benkay, 1985). Incidentally, artemisinin clinical trials, its production, and adoption was primarily executed in China throughout the 1970s (Tu, 2011; Zhang, 2012). Though it cannot be said that artemisinin and other Chinese anti-malarial inventions at the time were the catalyst for prompting the adoption of a patent system in China, it is fascinating that these scientific discoveries arose on the precipice of China's modernisation efforts to attract foreign investment and facilitate international technology transfer (Benkay, 1985). In 1982, the United Nations Development Programme, World Bank, and the World Health Organization held a Scientific Working Group meeting in Beijing where Tu Youyou presented her findings to increase the international exposure of her group's discovery (Tu, 2011). Tu's collaborator, Li Guoqiao, shared data with British scientists from The Wellcome Trust (a charitable health and science nonprofit), making artemisinin derived drugs more widely known (Faurant, 2011). In the wake of this collaboration, a French pharmaceutical company, Rhône-Poulenc Rorer (now Sanofi-Aventis), was the first Western manufacturer to license an artemisinin derivative: injectable artemether for severe and complicated malaria (Faurant, 2011). Negotiations were lengthened due to competing patent infrastructure between China and France (Faurant, 2011). Though China was granting Western

nations a right to exploitation[4], this privilege was withheld from Chinese patent holders in an effort to uphold socialist ideals within the country while promoting economic interests abroad (Benkay, 1985). This materialised as a patent system that was socialist at the domestic level, but capitalist at the international level (Benkay, 1985). Consequently, Rhône-Poulenc Rorer negotiated licensing through a Chinese state organisational intermediary rather than directly with the Chinese company—Kunming Pharmaceuticals (Faurant, 2011). Altogether, challenges associated with China's competing interests culminated in a four year long technology transfer effort, which included meetings being moved to Brazil, inappropriate documentation, and additional clinical testing (Faurant, 2011). Incidentally, none of the active ingredients used in artemisinin-based combination therapies are patented, meaning generic drugs can be freely produced by anyone (Orsi et al., 2018).Thus, the prevailing non-patent system upheld by China and later, along with the WHO, resulted in a more integrated philanthropic implementation of artemisinin. By comparison, antiretroviral therapies (ARTs) for the treatment of HIV/AIDS at this time were independently licensed by multinational pharmaceutical companies and, consequently, entirely financially inaccessible to countries in the Global South (Orsi et al., 2018). While the fact that artemisinin was rediscovered at a time when the pioneering country—China—did not have an active patent system, may seem serendipitous in hindsight, it ought to be revered now as a humanitarian standard for the development and distribution of life saving drugs in impoverished countries. However, there is still much to be learned from the global distribution of ACTs. While it is true that the unpatented ingredients gave any company the freedom to manufacture these antimalarials, few developers capitalised on this public domain landscape at the turn of the 21st century (Orsi et al., 2018). In 1993, Rhône-Poulenc Rorer was the first to

[4] Right to exploitation grants an individual or entity the rights to manufacture, reproduce, distribute, perform, license or sell a licensed invention

manufacture artemether for distribution to malaria affected countries (Faurant, 2011). In spite of the lower costs for ACT treatment when compared to HIV antivirals at that time, many African countries still struggled to afford it (de Magalhaes, 2004; WHO, 1994). Instead, they continued to rely on less effective antimalarials already on the market, such as quinine and chloroquine (WHO, 1994). At this time, an average treatment course/person of injectable artemether for patients too sick to consume oral medication was priced in USD at $4.80 in China, $5.20 in Myanmar, $31 in Thailand, and $30 in Brazil (once donated supplies from China were exceeded) (WHO, 1994). According to historical country data from the World Bank Group, the median household income in Thailand's rural and border regions—where malaria was actively endemic—was approximately $65 USD per month in 1993 (Natenuj, 2001). Consequently, purchasing a single course of this medication out of pocket would have consumed roughly 48% of a rural family's entire monthly earnings. In Brazil, the disparity was even greater for rural families afflicted by malaria. In rural and frontier regions, the minimum wage was approximately $50 USD, which means that an out of pocket treatment would have consumed 60% of a household's monthly earnings (Ferreira et al., 2006).[5] These values don't even account for the increase in cost that would be typical of those purchasing non-prescription artemisinin-based drugs on the black market (WHO, 1994).

[5] To make the 1993 medication costs comparable to local income, household earnings were converted into stable US dollars (USD). For Thailand, a typical low-income rural household budget (~$64.27 USD per month) was calculated by taking the individual poverty line of 618 Thai Baht per month and multiplying it by an average family size of 2.6 people (Natenuj, 2001). This total was then converted using the 1993 fixed exchange rate of 25 Baht to $1 USD (Nidhiprabha, 1996). For Brazil, tracking local income in 1993 was complicated by extreme hyperinflation, which caused local currency values to change daily. To overcome this, the baseline relies on national census data (PNAD, 1993), which tracks the standard, inflation-adjusted monthly minimum wage for rural and frontier workers, averaging a stable value of $50.00 USD per month during that period (Ferreira et al., 2006; World Bank, 1995). Both baselines capture the exact monthly cash available to a typical rural family in these countries.

By 2001, Novartis (a Swiss-based company), signed a 10 year agreement with the WHO to manufacture a fixed-dose combination ACT pill (artemether and lumefantrine); this specific formulation was patented in 1997 (Meier Zu Biesen, 2011; Orsi et al., 2018). The medication was distributed to the public sector at a zero loss-zero profit cost price negotiated between Novartis and the WHO of $2.40 USD (Orsi et al., 2018; Zhou et al., 1997). Non-fixed dose ACTs were also offered at this time for a lower cost ($1.30 USD), but the WHO favoured fixed doses as it was less reliant on high patient compliance (i.e., a patient would only have to take one pill at a time versus two) (Orsi et al., 2018). Since licensing of ACTs was predicated on WHO quality assurance, the 10 year agreement established with Novartis ended up triggering a quasi-monopoly (Orsi et al., 2018). To outcompete Novartis—in association with formulating their own ACT combinations—other companies also had to navigate WHO approval and fixed cost negotiation (Orsi et al., 2018). This is a completely different market entry barrier when compared to the traditional patent system. Once Indian pharmaceutical companies Ajanta Pharma and Cipla entered the market in 2005, the cost of ACTs began to steadily decrease and Sub-Saharan African countries, assisted by Global NGOs, were finally able to acquire more treatments (Orsi et al., 2018; PATH, 2025). Nonetheless, even with an increased number of producers, the agricultural supply of artemisinin is incredibly variable based on market demand (Mimura et al., 2011; Paddon & Keasling, 2014; Peplow, 2016). When there is a shortage of *A. annua,* the cost of artemisinin skyrockets and more farmers plant it the following year, thereby generating a surplus of artemisinin the following year that floods the market and drops prices (Peplow, 2016). This vicious cycle negatively affects the price stability of ACT.

Efforts to bring down ACT costs even further has been ongoing, particularly since the advent of The Medicines for Malaria Venture (MMV) in 1999, which closely followed the establishment of

the Roll-Back Malaria (RBM) campaign from 1992 (Aginam, 2002). To achieve the means of lowering drug costs while also maintaining the quality and infrastructure necessary for intensive research and development, MMV proposed a Public-private Partnership model (Aginam, 2002; Hentschel, 2002). Perhaps one of the most notable private-public relationships to emerge from this was that of a joint collaboration between Amyris Biotechnologies (UC Berkeley startup), Institute for OneWorld Health (San Francisco non-profit pharmaceutical company), and Sanofi-aventis (previously Rhône-Poulenc Rorer) (Mimura et al., 2011). The patents issued to these stakeholders were royalty-free licenses, which operated under the expectation of all involved that no royalties would be returned from their inventions when applied to malaria intervention (Mimura et al., 2011). The outcome of this collaboration was the semi-synthetic production of artemisinin using *Saccharomyces cerevisiae* (baker's yeast)—engineered yeast produced an artemisinin precursor (artemisinic acid), which was later converted to artemisinin through organic chemistry (Paddon et al., 2013; Paddon & Keasling, 2014; Ro et al., 2006, 2008). After UC Berkeley's initial breakthrough, plans to scale up the production of semi-synthetic artemisinin (SSA) with the help of Sanofi-Aventis began in 2013 (Kung et al., 2018). Sadly, in 2015, no SSA was produced and Sanofi sold off the manufacturing site by 2016 (Peplow, 2016). This decline was driven by a stabilisation of the agricultural artemisinin market as a result of established long-term purchasing contracts with ACT manufacturers (Peplow, 2016). Sanofi's economic incentive was a profit margin of $350-400 USD/kg of artemisinin, but at the time they started production of SSA, agricultural artemisinin was beginning to sell for less than $250/kg (Peplow, 2016). Thus, the heroic narrative that SSA represented a low-cost, high-volume alternative source for agricultural artemisinin (Paddon & Keasling, 2014) was downplayed as a "supplemental source" (Peplow, 2016). Efforts to break the cost/yield barrier of SSA is still

ongoing, and it is not yet commercially viable for SSA to completely replace agricultural artemisinin, though it does continue to contribute to the ACT market (Kung et al., 2018; Peplow, 2016; Upadhyay et al., 2025). Presently, high-yielding *A. annua* varieties exhibit a 40-50% cost advantage over SSA (Furiasse, 2025). The slowdown of SSA's rollout highlights a breakdown in the pathway from laboratory success to industrial-scale production, where early economic assumptions about cost advantage did not hold as global artemisinin markets evolved. As agricultural artemisinin became cheaper and more reliably supplied through established production and procurement systems, the expected economic advantage of semi-synthetic production was reduced. This case shows that the path from technological breakthrough to real-world impact depends not only on scientific progress but also on changing market conditions.

Artemisinin presents a compelling case study in pharmaceutical commercialisation due to its status as a non-patented, public health-driven treatment. While standard market forces like supply, demand, and competitive pricing apply, the ACT market is uniquely shaped by institutional gatekeepers: the WHO acts as an obligate intercessor through its prequalification guidelines, and The Global Fund serves as the primary financier[6] (Orsi et al., 2018; PATH, 2025). Northern firms like Novartis and Sanofi initially dominated the early 2000s due to rapid market entry and early WHO endorsement, but Southern generic manufacturers (e.g., China and India) later secured WHO qualification and quickly integrated WHO recommendations into their product development, consequently outcompeting European companies on pricing (Orsi et al., 2018; PATH, 2025). Though firms may be reluctant to enter the antimalarial market because of limited opportunities for patent-based price premiums, manufacturers that establish a foothold can nevertheless sustain commercial operations through a low-cost, high-volume procurement

[6] The Global Fund began financially supporting malaria intervention in 2005 (Le Menach & Anderson, 2025)

model supported by donor-funded purchasing and large public-sector contracts (Cohen et al., 2008; Orsi et al., 2018; Teo, 2023). Overall, ACT market trends demonstrate that first-mover advantage in this sector belongs to firms that rapidly adapt to and adopt evolving WHO clinical recommendations (Orsi et al., 2018; PATH, 2025). Thus, even as ACT resists certain market pressures and price hikes due to its philanthropic nature, quasi-monopolisation in this sector is still a risk due to these early entry advantages. For instance, although Ajanta and Cipla entered the generic ACT market in 2005, their products did not substantially affect pricing or expand treatment options in the African public-sector until the companies obtained WHO prequalification in 2008–2009 (Orsi et al., 2018; Tren et al., 2009). Even still, during that year, Kenya and Uganda experienced multiple issues regarding Ajanta's inability to fulfill contracts and several drug quality concerns issued to the company by the WHO (Tren et al., 2009). Whether such issues contributed to the late uptake of these drugs in other African countries is unclear, but Tanzania did not prequalify Ajanta's ACT until 2013 (Kilonzi et al., 2019). This represents a period of approximately 10 years when the African ACT market was essentially cornered by one company (Novartis) (Meier Zu Biesen, 2011). Might such scenarios provide a need for further checks and balances, or does it demand a complete rethinking of charitable drug development?

What this case study illustrates is the need for early integration of university, NGO, and business partnerships (Mimura et al., 2011) when it comes to humanitarian technological developments. A proactive approach must be taken at the level of discovery and beyond. Though scientists have a strong sense of the central societal challenges that motivate their research, there is yet a pervasive myopia that often prevents them from anticipating the downstream societal effects after a patent is filed or a technology is transferred (Stilgoe et al., 2013). Having the wherewithal

to address these downstream challenges within the laboratory first may require a concentrated institutional effort to bring scientists and social scientists in closer proximity to establish impactful working relationships. Therefore, as the pioneers of scientific discovery, scientists need to recognise that it is not just about engaging in partnership with other non-profit and corporate actors, but also about selecting the right kinds of actors. Building and growing a scientific workforce that can better understand societal challenges and engage in impactful partnerships to steward a technology from beginning to end will be essential in the field of drug discovery and implementation for a more equitable future.

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How Commercialisation of Artemisinin Impacts Local/Indigenous Knowledge and Medicinal Use in Africa

The Western pharmaceutical industry and traditional ecological/Indigenous knowledge are often portrayed as being at odds—prioritising the values and goals of one is typically antithetical to the values and goals of the other (Aginam, 2002; Swidrovich, 2023). China's path to adopting a Western patent system and the way it shaped ACT development is a great example of this (Benkay, 1985; Orsi et al., 2018). In other parts of the world, the commercialisation of artemisinin and its adoption by the WHO as a front-line treatment for malaria, drastically altered Indigenous relationships to the medicine (Aginam, 2002; Furiasse, 2025; WHO, 1994). In spite of the altruistic intent behind much of the artemisinin and ACT implementation, Indigenous groups were left outside of the decision making (Aginam, 2002). In 1994, the WHO referenced the Indigenous use of *A. annua* crude leaf extract in Myanmar as a potential regulatory problem and expressed concerns over the unregulated use of artemisinin in local communities that could lead to drug resistance and recrudescence of malaria in underdosed cases (WHO, 1994). Strategies were recommended and employed during and in subsequent years to surveil the usage of artemisinin in these communities, and restrict its informal use (Arnold, 1994; Phillips-

Howard, 1994; WHO, 1998). For those countries with their own ethnopharmacology, such as Tanzania, the dichotomy of a traditional folk medicine turned commercialised formulation resulted in a tension between the WHO, commercial Tanzanian growers of *A. annua,* and the rural poor (Meier Zu Biesen, 2011). To the commercial growers, artemisinin was perceived as a 'European' or 'modern medicine'[7], due to its affiliations with the WHO and particularly in relation to its co-formulation with lumefantrine in the fixed dose combination marketed by Novartis, which was widely distributed throughout the country in 2006 (Meier Zu Biesen, 2011). However, to traditional healers (who were already familiar with an Indigenous variety—*Artemisia afra*), and Tanzanian locals who used herbal treatments in their daily lives, it was widely considered traditional medicine[8]. Taking tea infusions of *A. annua* leaves assisted with insufficiencies in ACT supply caused by its sequestration to the public sector and its exorbitant expense in the private sector (Meier Zu Biesen, 2011). While the risk of malarial resistance due to artemisinin monotherapy was already being widely circulated by the WHO and was acknowledged by the locals, many Tanzanians felt they had no alternative (Meier Zu Biesen, 2011). This is where the deployment of medical interventions using centralised institutional mechanisms often fails. The WHO repeatedly expressed concerns over Indigenous medicinal use of *A. annua* but failed to properly surveil or at least capture and report how traditional use of the herb was changing in response to these recommendations, if at all—quantified reporting on this topic is not prevalent in any of their reports. Their most recent World Malaria Report does not address Indigenous use of *A. annua* and no longer references its contribution to resistance spread (Le Menach & Anderson, 2025). Rather, reporting that does exist for *A. annua* usage in local

[7] Dawa ya kizunga or dawa ya kisasa, meaning "white medicine" and "modern medicine" (Meier Zu Biesen, 2011).
[8] Dawa ya kienyeji

contexts is provided by grass-roots NGOs, like the "Action for Natural Medicine" network (ANAMED), that actually promote the unmitigated use of the plant as a low-cost, culturally responsive treatment (Aftab et al., 2018; ANAMED, 2026). This suggests that local use of *A. annua* for treatment falls outside of formal global malaria surveillance structures.

Despite WHO recommendations that have called for traditional medicine integration into national health care systems since 1972, antimalarial efforts present a case where these resolutions have not been successfully executed (Aginam, 2002; Furiasse, 2025; RITAM, 1999). The lack of Indigenous engagement and acknowledgement of traditional healing in these contexts has historically relegated Indigenous ethnopharmacology to the sidelines of malaria control (Aginam, 2002; Chapoterera et al., 2025; Nalongo, 2025). Very few African Indigenous healing remedies have undergone rigorous scientific testing, despite the widespread use of antimalarial plants documented across Nigeria, Uganda and Zimbabwe and numerous calls from NGOs to investigate their properties (Chapoterera et al., 2025; Nalongo, 2025). Additionally, African scholars have consistently called for an integration of traditional healing and African Indigenous medicine with Western medicine and ongoing malaria control strategies, not only with regard to the types and accessibility of medicines, but also with regard to African perceptions of these medicines (Aginam, 2002; Chapoterera et al., 2025; Nalongo, 2025; Oguamanam, 2003). Many traditional African healing traditions are multi-faceted and express an intrinsic interconnectedness with all things human and non-human—incorporating the healing of the body, mind and spirit (Aginam, 2002; Furiasse, 2025; Oguamanam, 2006). Therefore, a failure to ‘comply’ with WHO recommended malaria interventions, cannot simply be attributed to a lack of education or access—although these are certainly major contributing factors (Aftab et al., 2018; Meier Zu Biesen, 2011; RITAM, 1999). A preference for traditional methods or

locally procured *A. annua* teas, is also informed by African socio-cultural ideals, particularly that of self-reliance and independence (Aftab et al., 2018). Additionally, the historical use of *A. annua* is deeply embedded in the medical traditions of some African countries, particularly Madagascar, due to centuries old exchanges with eastern and southeastern Asia through trade (Furiasse, 2025). The Malagasy[9], incidentally, view *Artemisia annua* and their cultivation of it as a source of pride, also leaning into notions of self-reliance that extend into not only control over their own health, but control over their own therapeutic resources (Furiasse, 2025). The introduction of semi-synthetic artemisinin (SSA) threatened this socio-cultural ideal Madagascar's economy—they are a major grower of *A. annua* and also the only donor-funded supplier of artemisinin[10] outside of China (Furiasse, 2025; PATH, 2025). However, for reasons described earlier, the threat has not yet materialised and cultural resiliency has contributed to a resurgence in the growth and cultivation of *A. annua* in Madagascar (Furiasse, 2025).

Conclusion

Although the prevention of malaria is lauded as a cohesive globalisation effort, the consistent lack of acknowledgement of Indigenous worldviews, ideals and contributions at this scale sets a dangerous, but long-understood precedent: Western governance systems are perceived as superior to other systems and ontologies. Unfortunately, this contributes to the exacerbation of malaria driven health inequalities that the current system vows to address. Many of the world's rural poor still struggle to gain access to commercial public-sector ACTs (Le Menach & Anderson, 2025). Scholars, particularly within the fields of international law and anthropology, continue to press for a deeper socio-political investment in traditional knowledge and Indigenous

[9] This is the word used to refer to both the language spoken and the people that come from Madagascar
[10] Bionexx does not produce ACTs, only artemisinin. This document may sometimes cause readers to equate ACTs and artemisinin, but this is an important distinction in this case

medicine for addressing these disparities (Aginam, 2002; Furiasse, 2025; Meier Zu Biesen, 2011; Nalongo, 2025; Oguamanam, 2003; RITAM, 1999). Reliance on traditional therapies is often framed as a socio-economic coping mechanism among those for whom commercial ACTs are too expensive (Aftab et al., 2018; Aginam, 2002; Meier Zu Biesen, 2011). However, for the narrative to stop there would do many Indigenous groups a disservice. Many healing practices are socially integrated, built on established norms of spirituality, trust, and close human-nature relationships (Chapoterera et al., 2025; Furiasse, 2025; Meier Zu Biesen, 2011). Therefore, these norms ought to be respected and leveraged to close the gap of health inequalities in these settings, not abandoned. Academics in the natural sciences have a responsibility in recognising and understanding these realities to generate technological solutions that also uplift Indigenous ways of knowing and being. Becoming familiar with International Agreements, such as the Nagoya Protocol on Access and Benefit-sharing and United Nations Declaration on the Rights of Indigenous Peoples, that articulate these ideals is a good place to start. Bridging this knowledge gap in STEM fields will be critical for fostering a more inclusive and anticipatory technological academic workforce. Hopefully, this will usher in a new age of academic innovators that become more integrated into the translational and applied research space to increase access and benefit sharing for all people.

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