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Sensory Ecology, Bioeconomy, and the Age of COVID: A Parallax View of Indigenous and Scientific Knowledge

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Abstract

Drawing on original ethnobotanical and anthropological research among Indigenous peoples across the Amazon, we examine synergies and dissonances between Indigenous and Western scientific knowledge about the environment, resource use, and sustainability. By focusing on the sensory dimension of Indigenous engagements with the environment—an approach we have described as "sensory ecology" and explored through the method of "phytoethnography"—we promote a symmetrical dialogue between Indigenous and scientific understandings around such phenomena as animal–plant mutualisms, phytochemical toxicity, sustainable forest management in "multinatural" landscapes, and the emergence of new diseases like the novel coronavirus SARS-CoV-2 (COVID-19). Drawing examples from our own and other published works, we explore the possibilities and limitations of a "parallax view" attempting to hold Indigenous and scientific knowledge in focus simultaneously. As the concept of "bioeconomy" emerges as a key alternative for sustainable development of the Amazon, we encourage a critical and urgent engagement between dominant Western conceptions and Indigenous Amazonian knowledge, practices, and cultural values. Cognitive science, which has long contributed to studies of Indigenous categorization and conceptualization of the natural world, continues to play

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an important role in building bridges of mutual communication and respect between Indigenous and scientific approaches to sustainability and biodiversity conservation.

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1. Introduction

Even with English as the shared global language of scientific publication, cultural anthropologists and natural scientists are barely able to communicate with one another. The theoretical premises and methodological habits of the social and natural sciences are not so much contradictory as taking place on largely separate intellectual planes. For example, anthropologists working with Indigenous peoples of the Amazon have long been interested in how these diverse cultures conceptualize plants, animals, and environmental processes. However, the results of these fascinating investigations rarely have any impact on mainstream research by ecologists and conservationists working in the same region (Fernández-Llamazares & Virtanen, 2020). By the same token, the fascinating and often relevant work done by natural scientists on Amazonian environments and species is rarely taken into consideration in anthropological studies, which tend to focus on abstract, metaphysical conceptions of the natural world as found in myths, shamanism, and ritual practices (Shepard & Daly, 2022). The field of ethnobiology, deeply influenced by cognitive science, has long sought to bridge this gap (Berlin, 1992; Medin & Atran, 1999; Nazarea, 1999). Adopting a paradigm strongly allied to the natural sciences, however, the interdisciplinary dialogue between ethnobiology and cognitive science has largely excluded contemporary anthropological insights emerging from multispecies approaches and the "ontological turn" (Daly, Nic Eoin, French, & Miller, 2016; Ellen, 2016; Furlan, Jiménez-Escobar, Zamudio, & Medrano, 2020). While there are certainly powerful institutional forces at play in hampering interdisciplinary communication, these disciplinary divisions are themselves deeply rooted in the Cartesian divide between mind and body that lies at the very foundations of contemporary Western philosophy and science (for a useful discussion on this point, see Hornborg, 2006).

Given the cascading social, environmental, and climate crises, it seems ever more urgent to build bridges of dialogue between the human and natural sciences, and even more importantly, between Western and non-Western conceptions about nature, humanity, and the environment. To this end, we present our own efforts to encourage a symmetrical exchange between Indigenous Amazonian and Western scientific understandings of ecological processes and the burgeoning environmental crisis, in the hopes that these methods and concepts could inspire others. In the context of this special issue, we draw on our own research and the work of others to suggest avenues of methodological and theoretical exchange between contemporary Amazonian anthropology and cognitive science, building on but also transforming existing approaches from ethnobiology. Specifically, we present case studies drawn from our collaborative work in Amazonia into Indigenous and scientific understandings of ant–plant

mutualisms, toxic compounds used in traditional medicine and shamanism, the formation of domesticated forest landscapes, and the COVID-19 pandemic.

In examining synergies between Indigenous and Western science while also acknowledging profound epistemological and ontological differences, we borrow Ginsburg's (1995) concept of the "parallax effect." In her analysis of the frictions between aboriginal and conventional approaches to film, Ginsburg uses the phenomenon of parallax, borrowed from the field of optics, as a metaphor for the new perspectives offered by Indigenous peoples' "slightly different angles of vision" (ibid, p. 65). In a similar way, we suggest that Indigenous and Western understandings of the natural world should be seen, not so much as in opposition, but rather in a productive tension that reveals new vistas and deeper insights into shared and urgent contemporary human dilemmas.

2. Indigenous and Western science: Possibilities and limitations of dialogue

Mind/body dualism is the foundation for what Latour (1993, p. 12) refers to as "the Great Divide" between the human (Culture) and nonhuman (Nature) realms that characterizes modern Western thought. The mind/body dichotomy is not such a problem for Amazonian Indigenous peoples (e.g., Barreto, 2022; McCallum, 1996; Taylor, 1996; Viveiros de Castro, 1996), but it is for Western scientists, anthropologists, and policymakers, who are constantly tripping over Cartesian dualism and the related nature/culture divide in their efforts to implement sustainable development goals. There is no doubt that the reductive, rationalist principles established by Descartes and other early Enlightenment philosophers and scientists contributed to the phenomenal growth and success of Western science and technology over the ensuing centuries. However, as the global ecological crisis puts the biosphere and humanity itself under greater threat, we are witnessing the drastic and perhaps unavoidable negative impacts of a philosophical viewpoint that objectifies nonhumans and even other human beings, elevates humanity outside of the natural world, and commodifies everything.

Indigenous conceptual systems, by contrast, are built upon a more fluid ontology that incorporates "natures" and "cultures" into an integrated, relational whole. Perhaps the most important contribution of Amazonian anthropology to contemporary social theory has been its exploration of the subjectivity of nonhuman beings through the lens of Indigenous ontologies, mainly via the intellectual currents of "animism" (Descola, 1994) and "perspectivism" (Viveiros de Castro, 1996). The personhood of animals is central to Viveiros de Castro's formulation of perspectivism, where, according to Indigenous concepts, each species sees itself as a person with a human body and culture, while other species are perceived according to their "cosmological perspective" as determined by predatory relationships: The peccary sees itself as a person but regards human hunters as predatory jaguars, while the jaguar sees itself as a person and regards humans as peccaries to be hunted (Viveiros de Castro, 2002). In this "cosmos-as-ecosystem," predation is a central metaphor governing social, ecological, and symbolic exchanges between humans, animals, and spirits (Århem, 1996; Fausto, 2007; Reichel-Dolmatoff, 1976).

In Amazonian lifeworlds, the entire human life cycle, from birth and growth through senescence, death, and decay, integrating biological and social dimensions on the individual as well as collective scales, always includes vital nonhuman actors, whether biotic, abiotic, or spiritual (Kohn, 2013; Santos-Granero, 2012; Seeger, Da Matta, & Viveiros de Castro, 2019[1979]; Shepard, 2004; Zent & Zent, 2022). Thus, the intertwined spiritual and ecological lifeworlds of Amazonian Indigenous peoples harness the agency of plants, animals, spirit beings, landscape features, and other nonhuman persons in an integrated sphere of relationships. In these Indigenous Amazonian philosophies of life, the soul is embodied, and the body is ensouled (Daly, 2021; Shepard, 2018). In contrast to Cartesian metaphysics and its dualistic ontology, then, Amazonian Indigenous peoples tend to see the physical and the spiritual, the material and the intangible, body and mind, and ultimately nature and culture as intermingled and interdependent rather than opposed, though of course these categorical distinctions are themselves conceptually problematic (Descola, 2013).

The practical result of these non-Cartesian philosophies is that Indigenous peoples of Amazonia and other parts of the world turn out to be better stewards of biodiversity than their non-Indigenous counterparts (Estrada et al., 2022), even though these outcomes are not necessarily predicated upon explicitly conservationist practices. As humanity faces unprecedented social, ecological, and epidemiological crises, a growing number of scholars suggest that active collaboration with Indigenous knowledge systems should be a significant part of global conservation and sustainability strategies (Athayde et al., 2021; Chapin, 2004; Estrada et al., 2022; Fernández-Llamazares & Virtanen, 2020; Franco-Moraes et al., 2019; Tom, Huaman, & McCarty, 2019). Yet given the noted differences between Indigenous and Western scientific epistemologies, not to mention the inherent power asymmetries, what are the possibilities, risks, and limitations inherent to such exchanges?

Comparing Native and Western science, Native American ethnobotanist Linda Black Elk has written, "Native science has at its foundation the very same scientific method that we, as researchers trained in the Western world, all hold so near and dear"—that is, detailed observation and experimentation—yet at the same time, "Native science also differs from Western science in that it is based on *participation* with the natural world. We do not separate ourselves from the Earth's processes" (Black Elk, 2016, pp. 3-4; our emphasis). Indigenous worldviews tend to emphasize the holistic, relational connections between diverse elements of the biosphere, including plants, animals, rocks, landscape features, and importantly, human beings. These connections are often conceived as kindred relations (see, for instance, Rarámuri ethnobotanist Enrique Salmón, 2000, on "kincentric ecology"; see also ojalehto mays, Seligman, & Medin, 2020, on "folk communication" among the Ngöbe people of Panama).

Western and Amerindian knowledge systems have been in dialogue, in some sense, since the Age of Exploration, though it was hardly a fair or two-sided exchange. The influx of vast amounts of plant material from the New World and other tropical regions beginning in the 16th century caused a revolution in the botanical sciences, ultimately resulting in modern Linnaean taxonomy (Bartlett, 1940; Ford, 1978). Of course, this interest in new botanical material was hardly just academic: The original motivation for the "discovery" of the New World was European navigators' search for alternative routes in the lucrative spice trade. Early colonial explorers, physicians, missionaries, and scientists received instructions to be on the lookout

for "fruits and seeds, all kinds of spices, drugs, perfumes… trees, plants, herbs, fruits… and medicines" (Latorre, 1914, p. 301). Important pharmaceutical and industrial products like quinine, strychnine, curare, ipecac, rubber, kapok fibers, and many others represent direct appropriations of Indigenous Amazonian knowledge, though this intellectual debt is seldom even documented, much less acknowledged or compensated (Sanjad et al., 2021).

Beyond such crassly utilitarian interest, ethnographers and ethnobiologists have long marveled at the sophisticated taxonomic and ecological knowledge Indigenous peoples maintain about plant and animal species, ecological processes, and forest habitats, including elements that may complement or even rival contemporary scientific understandings (Abraão, Nelson, Yu, & Shepard, 2008; Bang, Marin, & Medin, 2018; Boster, Berlin, & O'Neill, 1986; Bulmer, 1974; Conklin, 1954; Fleck & Harder, 2000; Franco-Moraes et al., 2019; Kimmerer, 2013; Parker, Posey, Frechione, & da Silva, 1983; Shepard, Yu, Lizarralde, & Italiano, 2001; ojalehto mays, Seligman, and Medin, 2020). Nonetheless, such ethnobiological studies tend to focus on practical, morphological, and taxonomic questions that appear to show congruency or complementarity between Indigenous and scientific systems, while steering clear of deeper ontological questions that appear radically different, even incommensurate (Furlan et al., 2020; Sheldrake, 2020; Prado, Murrieta, Shepard, de Lima Souza, & Schlindwein, 2022).

To even begin to engage in a more productive, symmetrical and mutually beneficial dialogue between Indigenous and scientific knowledge, we must first acknowledge the important differences in their ontological bases and social, philosophical, historical, and practical functions. Viveiros de Castro (2004b, p. 8), for example, warns about the dangers of "silencing the Other by presuming a univocality—the essential similarity—between what the Other and We are saying." There is no question that Indigenous and scientific ways of acquiring, transmitting and acting on knowledge about the so-called natural world are fundamentally different in many ways, starting from the very definition of what comprises "nature" (Descola, 1994; Rival, 2012; Zent, 2015). Moreover, there is no homogeneous, unified body of "Indigenous knowledge" on which to base such comparisons since Indigenous people represent linguistically, culturally, historically, and internally diverse human groups spread across the globe in often dramatically different political, social, and economic situations.

Indigenous peoples have been defined as "ethnic groups who are descended from and identify with the original inhabitants of a given region" (Reyes-Garcia et al., 2019). Indigenous and local knowledge, sometimes referred to as traditional ethnoecological knowledge (TEK) by ethnobiologists (e.g., Hunn, 1993), has been defined by the United Nations as follows (IPBES, 2016, par. 5[a]):

> Indigenous and local knowledge systems are understood to be dynamic bodies of integrated, holistic, social and ecological knowledge, practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environment. Indigenous and local knowledge is grounded in territory, is highly diverse and is continuously evolving through the interaction of experiences, innovations and different types of knowledge (written, oral, visual, tacit, practical and scientific). Such knowledge can provide information, methods, theory and practice for sustainable ecosystem management. Indigenous and local knowledge systems have been, and continue to be,

empirically tested, applied, contested and validated through different means in different contexts.

Although now codified in international law and development discourse (e.g., the UN Declaration on the Rights of Indigenous Peoples, 2007), the moniker "Indigenous" is a highly politicized category, replete with historical complexities and contestations in Amazonia and beyond (Carneiro da Cunha, 2009; Kenrick & Lewis, 2004; Ramos, 2003). It would be difficult to attempt a general comparison of "Indigenous knowledge systems" with Western science (see Bang et al.'s, 2018, discussion of Kimmerer, 2002, on TEK and Indigenous science), given that the scope of such a comparison would include vastly distinctive types of knowledge, from fully systematized bodies of professional practice such as Ayurveda or traditional Chinese medicine, codified in written texts for thousands of years, to the threatened and virtually unknown ethnobiological classification systems of isolated Indigenous peoples of the Amazon. Focusing on the Amazon region, however, certain general shared features of cosmology, ontology, and ethnoecological classification have been noted (Abraão et al., 2008; Boster et al., 1986; Descola, 1994; Parker et al., 1983; Rival, 2012; Viveiros de Castro, 2004a). In this case, we hazard a general outline of major differences as well as some shared features as a preface to any further attempts at dialogue between Western and Indigenous knowledge systems.

Despite multiple revolutions in scientific thought over the past century, the Western scientific method, especially within disciplines allied to biodiversity conservation, remains largely rooted in a Newtonian paradigm based on stable, observable identities, the notion of a single Truth, the importance of measurement, and the primacy of language, especially mathematical language, as an objective description of reality. Despite the quantum revolution, many Western scientific disciplines remain firmly rooted in positivism, premised on a stark separation between observer and observed. The objectification of research subjects is associated with quantification, reductionism, universalism, and statistical analysis aimed at discerning cause and effect. Such scientific methods are also closely allied with capitalist political and economic structures based on thoroughly naturalized assumptions about individualism, competition, accumulation, private ownership, and the commodification of knowledge and nature itself (Hartigan, 2017; Helmreich, 2016; Latour, 1987; Latour & Woolgar, 1979; Tsing, 2004). As Myers (2015) observes, Western science is also inextricably bound to its racist, sexist, economizing, and heteronormative history.

Indigenous Amazonian ways of knowing are associated with radically different social, epistemic, ontological, and economic premises. Where Western science seeks to objectify that which is to be known, Amazonian knowledge systems take the opposite tack. As Viveiros de Castro (2004a, p. 468) observes:

> Amerindian shamanism is guided by the opposite ideal. To know is to personify, to take on the point of view of that which must be known. Shamanic knowledge aims at something that is a someone—another subject. The form of the other is *the person*.

Rather than being reductionist, Amazonian and other Indigenous knowledge systems are *integral*, in the sense that technical aspects of hunting, horticulture, and other environmental practices cannot be separated from the religious beliefs, rituals, myths, and social organization that make food production possible and meaningful. As Conklin (1957, p. 2) remarked of the Hanunóo people of the Philippines, "One of the most significant considerations… is the extent to which the agricultural system is integrated with other systems in the sociocultural matrix." Though Amazonian and other Indigenous peoples are increasingly turning to text-based and even audiovisual and hyper-text technologies to document and preserve their knowledge (Conklin, 1997; Shepard & Pace, 2021; Turner, 1992), the basis of these knowledge systems throughout nearly all of their history has been through direct, oral transmission in hands-on, mostly nonformal learning contexts, very different from the highly formalized, mostly written, and preferentially mathematical basis for communication and transmission in Western science.

Though not universally the case, much of Amazonian Indigenous knowledge about the natural world is widely shared throughout the population, though subject to strong segregation by gender and great variability across individuals and age groups. Some forms of specialized knowledge, however, such as that held by shamanic healers or midwives, may in fact be more private and reserved and sometimes require significant economic investments to acquire through apprenticeship. While Western scientific knowledge at least attempts to be universal, Indigenous knowledge is closely tied to specific geographical and cultural regions and circumscribed territories. Combined with the active, lived nature of knowledge transmission, this gives local knowledge an intimate, embodied, and highly detailed character that can be seen as different from but also complementary to the universalizing language of Western science.

Finally, there are clearly different religious, ethical, and economic underpinnings to Indigenous Amazonian knowledge when compared with the Western scientific paradigm. Yanomami shaman Davi Kopenawa (Kopenawa & Albert, 2013, p. 149) describes the ecological concept of *në rope*, translated as "value of growth," which represents the "invisible hand" regulating Yanomami economy:

> The value of growth remains abundant in the forest and if our gardens take the value of hunger, our shamans drink the *yãkoana* [psychoactive shamanic snuff] to bring it back home. And if need be we can also borrow the forest's fertility from a friendly house… When the forest's richness runs away, the game becomes skinny and scarce, for this richness is what makes game prosper… To live, their images must feed on the image of the forest's value of growth. This is why the shamans also bring down the image of the game's fat with that of the forest's fertility.

Such conceptions that bind ecology, economy, morality, and spirituality present a stark contrast to Adam Smith's notions about the determinant role of supply and demand shaping Western capitalist markets. Closely tied to such economic and moral considerations, the thorny question of patenting nature, privatizing and commodifying traditional knowledge, and the elusive promise of sharing benefits from bioprospecting create additional barriers and justified resistance to exchanges between Indigenous and Western science (e.g., see Conklin, 2002).

With such fundamentally distinctive ideological, epistemological, social, ethical, and technological bases, it might appear that Indigenous and scientific knowledge would be entirely incommensurate, with no common ground on which to reach any form of dialogue. And yet time and again, ethnobiologists around the globe have commented on the sophistication of Indigenous taxonomic knowledge about plant and animal species, often rivaling or surpassing that of contemporary scientists (Abraão et al., 2010; Bulmer, 1974; Conklin, 1954; Fleck & Harder, 2000). In one particularly noteworthy case from Amazonia, Boster et al. (1986) describe the remarkable congruities between Aguaruna Indigenous taxonomies for woodpeckers and the corresponding scientific classification.

In his foundational text on ethnobiology, Berlin (1992) draws on evidence from ethnography, linguistics, and cognitive science to document apparently universal patterns observed in ethnobiological classification systems across the world and throughout history, including Western folk botanical traditions that gave rise to scientific taxonomy. While accounting for significant linguistic, geographical, and individual variation, Berlin posits universally shared features of human cognition that, when confronted with the taxonomic disjunctions observed in the natural world, result in broadly similar folk biological systems. European folk biological classification systems, which reach back to Antiquity and laid the perceptual foundations of Linnaean taxonomy (see Bartlett, 1940), are no exception, showing remarkable similarities to Indigenous folk taxonomies. Indeed, Bang et al. (2018) argue that Western (European and Euro-colonial) and Indigenous folk or "lay" knowledge systems are more similar to one another than to the peculiar ways of thought of trained Western scientists. On the other hand, Ingold (2000) suggests that scientific and Indigenous or "folk" ways of knowing are not entirely incommensurate. Beyond the overt similarities between scientific and folk taxonomies of species and ecosystems, Ingold also points out the sometimes hidden importance of hands-on, trial and error, "oral" knowledge transmission even in scientific apprenticeship. Ingold (2000, p. 20) draws attention to the ways in which close observation of the natural world can lead to transformative perceptions and insights, inviting human curiosity to follow cues and seek patterns (see also Black Elk, 2016).

While heeding Viveiros de Castro's (2004) warnings about "silencing the Other," we provide here several examples from our own work and the literature that lay out a pathway for respectful, meaningful, and mutually illuminating exchanges between Indigenous and scientific ways of knowing, which pay heed to points of alignment and convergence while also striving to take seriously the epistemological and ontological differences at play (see also Rival, 2014). Crucially, various Latin American scholars have pointed out how such ontological disjunctures and dissonances are imbued with asymmetrical power relations, and thus have called for a decolonization and radical retheorization of these politics (Blaser, 2009; de la Cadena, 2011; Rivera Cusicanqui, 2012).

3. The ant, the shaman, and the scientist

Scientific discoveries often happen in unlikely situations. And so, deep in the tropical rainforest of Manu National Park, Peru, a discussion between a Matsigenka shaman and a

Harvard ecologist led to a significant discovery about ant–plant mutualisms (Shepard, 2011), while reviving a century-old debate in tropical ecology between Richard Spruce and Alfred Wallace (see Edwards, Frederickson, Shepard, & Yu, 2009). Douglas Yu, then working on his PhD at Harvard University under the mentorship of E. O. Wilson, was visiting the Matsigenka community of Yomibato, where author Shepard was carrying out ethnobotanical research. Yu was studying the mutualistic relationship between several species of ants and the plant *Cordia nodosa*, a bristly tropical shrub related to borage (*Borago officinalis*). The *Cordia* plant offers the ants protective corridors of bristly hairs along its stems as well as large swollen branch nodes, which the ants hollow out to make nests. In return, the ants protect the host plants from other insect predators and, in some cases, clear out competing vegetation, creating notable clearings in the understory. Local Quechua-speaking colonists refer to these clearings as "Devil's gardens" (*supay chacra*).

The Matsigenka people also recognize the mutualistic relationship between ants and the *Cordia* shrub. Indeed, the Matsigenka word for the plant is *matyagiroki*, which means "arboreal ant shrub," where *matyaniro* refers generically to a number of ant species frequently encountered on plants and leaves, like *Allomerus*, *Azteca*, *Myrmelachista*, and the miniature fire ant, *Wassmania*. Ants and other insects involved in such mutualistic relationships with plants are referred to generically as *iriite*, "its (i.e., the plant's) larvae," a term otherwise reserved for the larval stage of insects, and generally implying multiplicity, that is, not a single larva but a large, almost uncountable number. Thus, plant–insect mutualistic relationships for the Matsigenka are couched in ontogenic vocabulary, implying that the host plant is a kind of adult or "parent" to the fragile, multitudinous larval insect "children."

For the Matsigenka, the clearings found around *Cordia* plants are the work of spirit beings known as *Saankariite* (also written *saangariite*), a term that has previously been glossed as "pure" or "invisible ones" (Rosengren, 1998; Shepard, 1999, 2018) or "invisible beings, good spirits, angels" (Snell, Collants, Chavez, Cruz, & Pereira, 2011). *Saanka-* is a Matsigenka verb root referring to purity, cleanliness, transparency, invisibility, and erasure, as in *saankiaari,* "clean, transparent water" or *saankagantsi,* "to clean, purify, fade, erase, disappear." However, the word *Saankariite* also incorporates the noun suffix *-iite* noted above, referring to insect larvae and mutualistic plant–insect relations. Thus, the literal translation of the term is "invisible larvae," making a direct allusion to plant–insect mutualisms. A looser gloss might be "invisible swarm," highlighting their multitudinous nature.

Matsigenka shamans come to these spirit clearings and consume powerful psychoactive preparations such as tobacco paste, ayahuasca (*Banisteriopsis caapi*), or the *Datura*-like toé (*Brugmansia suaveolens*; Shepard, 1998, 1999). With the aid of such visionary plants, the shaman perceives the true nature of these mundane forest clearings: They are the villages and swidden gardens of multitudinous, capricious, and powerful human-like spirit beings, who are unimaginably distant and inaccessible under ordinary states of consciousness. While in trance, the shaman enters the invisible village and develops an ongoing relationship with a spirit "brother" (*ige*) or "sister" (*incho*) among the *Saankariite*, who can provide him or her with esoteric knowledge, news from distant places, healing power, artistic inspiration, auspicious hunting, and even novel varieties of food crops or medicinal plants from their gardens (Shepard, 1999).

As empirical proof of this hidden reality, the Matsigenka shaman Mariano Vicente Kiche pointed out tree trunks adjacent to the *Cordia* clearing, noting a profusion of swollen, scar-like nodules: "These are the burn marks caused by fires set by the *Saankariite* every summer to clear their gardens," he explained.

Yu, who had been researching the *Cordia* ant–plant relationship for years, had never observed this phenomenon. Dozens of trees around this large stand of *Cordia* were pocked with similar "burn marks." Intrigued, Yu cut into these formations with his pruning shears and found nests teeming with *Myrmelachista* worker ants that appeared to be galling the trunks to create additional housing, thus ensuring colony longevity. As detailed in *American Naturalist* (Edwards et al., 2009), this was the first recorded example of ants galling plants, thus resuscitating a pet theory of Spruce's that Wallace and later naturalists had rejected. This galling and colony-forming behavior, apparently unique to *Myrmelachista*—and as revealed by a Matsigenka shaman's keen insights—was also crucial in helping Yu fully characterize the ecological conditions shaping the mutualistic niche shared by three competing ant species.

In addition to such direct contributions to a scientific discovery, the striking Matsigenka conception of an "invisible swarm" of multitudinous spirits living in unseen villages suggests a fractal relationship between shamanic knowledge and observable ecological processes. Beyond abstract symbols or spiritual metaphors, these shamanic observations appear to relate to the living world as through a cosmological microscope, drawing nonarbitrary connections between microcosm and macrocosm, and relating ecological to cosmological processes. There is of course a clear ontological distinction between the scientific paradigm and the Indigenous view of these phenomena. However, by holding the ecological perspective in one eye and the cosmological perspective in the other, we can imagine bringing both views into overlapping focus onto a novel, stereoscopic vista, and thus unveil a richer, more comprehensive, and interesting landscape, analogous to what Ginsburg (1995) has described as the "parallax effect" in Indigenous cinema (see above).

4. Magic darts and messenger molecules

A similar parallax between Indigenous and scientific insights was revealed in a collaborative investigation by the authors into a category of "charm plants" known as *bina* by the Makushi people of Guyana. Daly describes an interview with Makushi elder John Samuels in a Makushi village on the Rupununi River concerning *waawî* spirit darts that shamans (*pia'san*) are said to acquire from *bina* plant charms (Daly & Shepard, 2019; see also Daly, 2015; Van Andel, Ruysschaert, Boven, & Daly, 2015). These spirit darts are fired during shamanic warfare and extracted from patients' bodies during healing rituals. Grandpa John described them as "tiny crystals… an arrow, but with macaw feathers" (Daly & Shepard, 2019, p. 13). Shamans are able to shoot these darts at their enemies: "like a missile, like starlight. But it is invisible to us. That arrow shoots into your chest and kills you straight away" (ibid.). He made a miniscule drawing (about 8 by 15 mm) in Daly's field notebook showing a cluster of pencil lines to illustrate the spirit darts he observed during shamanic training in his youth. Having imagined something more elaborate, Daly was initially disappointed in the tiny sketch, attributing its poor quality to John's arthritis and failing eyesight.

Several years later, the authors worked together examining the botanical identification and chemical properties of different *bina* species for clues as to how the Makushi understand and use these plants. Although botanically diverse, the botanical group most frequently associated with *bina* is the Araceae or calla lily family. Many Araceae species, including important *bina* varieties, contain toxic compounds known as raphides, which consist of needle-like, microscopic crystals of calcium oxalate that are responsible for the "stinging, irritating, and inflammatory activities of Araceae plant tissues," referred to in the medical literature as "the needle effect" (Konno, Inoue, & Nakamura, 2014). These microscopic needles can cause severe bodily reactions in humans (and other herbivores) by facilitating the transmission of toxic phytochemicals through the skin or internal membranes within the body.

These phytochemical insights into the toxicity of *bina* plants led us to appreciate Uncle John's sketch of *waawî* spirit darts in a new light. Though Makushi shamans have never examined calcium oxalate crystals under a microscope, their detailed knowledge of the chemosensory qualities and physiological effects of these and other toxic, medicinal, and bioactive plants have allowed them to understand these microscopic processes through the surprisingly accurate metaphor of the spirit-dart: in a revealing point of convergence between scientific and shamanic understandings, these plants are in fact riddled with pathogenic crystalline "needles" that are invisible to the naked eye. The example of Makushi spirit-darts demonstrates the multiscalar and integrated character of shamanic philosophy, which oscillates between—and sometimes inverts—the micro- and macroscopic scales in transiting the various levels and dimensions of the shamanic multiverse (see also Giraldo Herrera, 2018).

Raphide toxicology may also play an entirely overlooked role in the widespread phenomenon of attack sorcery or "dark shamanism" in the Guianas, known regionally as *kanaimà* (Butt Colson, 2001; Daly & Shepard, 2019; Whitehead, 2002; Wilbert, 2004). According to the Makushi, *kanaimà* are malevolent shamans who use a portfolio of secret *bina* plant charms to obtain illness-inducing darts, which are used to maim and kill their victims. *Kanaimà* are said to poison their victims before piercing their tongue with snake fangs, such that tongue and lips are swollen shut, and then scraping away the sphincter muscles of the rectum with an iguana or armadillo tail, leading to intestinal incontinence. Anthropologists have interpreted the specific symptoms of *kanaimà* sorcery as an inversion of ingestion—mouth swollen shut like a sphincter, rectum open like a mouth—associated variably with a structural inversion of shamanistic healing, a social response to envy, a vestige of colonial violence, or a form of Indigenous resistance (Butt Colson, 2001; Whitehead, 2002). Yet these are also precisely the symptoms caused by ingesting significant doses of raphide-containing Araceae, which have particularly toxic effects on mucus membranes around the mouth and anus (Desphande, 2002, p. 553; Hayes, 2008, p. 990).

This is not to say that raphide chemistry obviates the essential historical, sociological, and symbolic investigations by anthropologists on *kanaimà* sorcery in the Guianas, nor does it explain away the more widespread phenomenon of sorcery darts throughout Amazonia (see Chaumeil, 1993). Rather, the unexpected congruence between Indigenous and scientific insights into *bina* toxicity reveals a striking chemosensory logic connecting Makushi ethnobotany with these broader cultural ideologies, enriching both anthropological and pharmacological understandings of these complex biocultural practices. We have dubbed this

approach "sensory ecology" and have described the attendant interdisciplinary methodology as "phytoethnography" (Shepard & Daly, 2022; Daly & Shepard, 2019; Shepard, 2004).

5. Multinatural landscapes of Amazonia

Moving beyond the scale of individual plants and substances and their "sensory ecologies" in Amazonian shamanism, we have also sought to apply a parallax view to Indigenous understandings of ecological processes shaping tropical forest biodiversity. Recent studies have pointed to persistent floristic legacies left by pre-colonial and historical Indigenous peoples through conscious and unconscious management practices, some of which are ongoing (Fausto & Neves, 2018; Franco-Moraes et al., 2019; Levis et al., 2018; Lins et al., 2015; Shepard & Ramirez, 2011). Amazonian Indigenous peoples appear to have invested their efforts in domesticating cultivated species in gardens as well as wild populations of plants in actively managed agroforests and surrounding forest landscapes (Clement et al., 2015). In this way, some Amazonian landscapes have been transformed into cultural or ancestral forests (Balée, 2013; Franco-Moraes et al., 2019; Rival, 1998) that appear natural to the eyes of colonizers but are in fact anthropogenic in origin.

For example, Franco-Moraes et al. (2019) analyzed the floristic composition of mature, apparently primary forests located in the territory of the Baniwa Indigenous people of the northwestern Brazilian Amazon. Prior studies predicted that forests in the region would not show signs of significant anthropogenic alteration of species composition (Bush et al., 2015). However, working in old-growth forests near ancient village sites identified by the Baniwa, the authors encountered "ancestral forests" with as much as 57% of the tree biomass consisting of wild fruit trees managed by the Baniwa, compared to only 10% of such species in "immemorial forests" with no memory of past habitation or management by the Baniwa. Participatory mapping and direct observations revealed ancestral forests to be widely distributed throughout the region, whereas old-growth forests are rare. Yet structural analysis reveals ancestral forests to be nearly indistinguishable from immemorial forests: to an ecologist or botanist, both would appear to be pristine and natural.

Such domesticated Amazonian forested landscapes represent the multispecies outcomes of intentional and unintentional practices, accumulated over countless generations. As such, they represent social spaces that have been harnessed for human purposes, yet without excluding the multitude of other species and their associated ecological functions. Thus, to call such modified forests merely "anthropogenic" simplifies Indigenous worldviews and livelihood practices, which acknowledge the agency of multiple species and beings in their formation (Oliveira, 2016; Oliveira et al., 2020). Moreover, the socioenvironmental processes that have generated cultural forests also act in the reverse direction, leading to the "forested" cultures of Indigenous Amazonian peoples (Franco-Moraes et al., 2019; Shepard & Daly, 2022), for whom ecology and biodiversity are essential components of myth, ritual, and cosmology (Reichel-Dolmatoff, 1976; Århem, 1996).

Borrowing from the work of Viveiros de Castro (2002, 2004), we have developed the concept of "multinatural landscapes" in Amazonia. According to Amerindian concepts, all living

beings are, fundamentally, persons, sharing a universal human culture, while the "natural" biological form varies from one species or being to another. Culture, here, is a trans-specific quality shared by all sentient beings (animals, plants, and other beings), typically conceived of as "other-than-human persons" (Hallowell, 1960). Viveiros de Castro describes this as a "multinatural" ontology, in contrast to the "multicultural" Western notion of a universal, biological nature underlying the myriad variations of human language and culture (1998, 2004b).

According to Viveiros de Castro, Amazonian ontologies imply not a single, unifying biological nature, but rather a multiplicity of natures that may vary according to diverse cultural conceptions about the nature/culture relationship. In this regard, the study by Lins et al. (2015) highlights an additional nuance to our concept of multinatural landscapes: namely, distinctive archaeological cultures in the central Amazon seem to produce measurably different floristic legacies, detectable a millennium after the sites were abandoned. In other words, cultural diversity in the past, acting through variable cultural habits, management practices, and food preferences, can result in distinctive botanical signatures in the landscape that persist for centuries. Like a living tapestry, the forest bears the fingerprints of prior human activity, stretching back many generations and linking Indigenous societies and their territories into a complex historical web of human–forest mutualisms. Domesticated crops and other kinds of vegetal infrastructures undergird these cultivated landscapes, shaping them in partnership with human beings through deep historical time (Daly, 2021; Rival, 1998).

Indigenous peoples of the Amazon depend on standing forests for their livelihoods, and they have shaped these 'multinatural landscapes' to suit their own needs through time, in parallel to the needs of multiple other species and beings. This realization fundamentally transforms our understanding of biodiversity conservation and resource management in regions with long-term Indigenous occupancy. It is especially urgent to acknowledge the role of Indigenous peoples in shaping Amazonian biodiversity in the current context of the Anthropocene (Erickson, 2022; Hornborg, 2017; Kawa, 2016; Latour, 2017; Lorimer, 2012). Incorporating Indigenous knowledge and practices into the conservation framework is vital for both biodiversity conservation and Indigenous rights (Chapin, 2004; Estrada et al., 2022).

6. Revenge of the bat people

The COVID-19 pandemic caught most of the world by surprise. However, Indigenous peoples of the Amazon have had centuries of experience dealing with deadly epidemics. While global emergency measures such as social distancing, travel restrictions, and lockdowns were unprecedented in the recent history of Western public health, Indigenous peoples have long used the strategy of "voluntary isolation" to protect themselves from the immunological and existential threats of European colonization (Shepard, 2016). While some governments hesitated or struggled to impose such unusual restrictions on their populations, Indigenous peoples across the Amazon took the lead by declaring self-imposed quarantines and village lockdowns to avoid the introduction of this virulent new disease to their communities (Shepard, 2020).[1] As Tuyuka priest Justino Sarmento Rezende (2020) of the Upper Rio Negro in Brazil reflected on his own childhood:

> I was born far from the city, at "Jaguar-Creek." Whenever my father heard that a dangerous disease was coming, he took us to an even more isolated place. There, we waited until the latest news finally reached us: "the disease has passed." We had no doctors or nurses to take care of us. But we were watched over constantly by our sage grandparents who performed protective ceremonies using white pitch incense to fumigate the environment, the people and their pets… This current time with its current viruses, with their own proper names, it takes me back to the past and reminds me of the wisdom of my grandparents who helped to defend life.

In addition to their proactive and in many cases effective responses to the COVID pandemic, Indigenous communities also developed their own understandings of the disease's origin in dialogue with evolving scientific information as it circulated through the news and social media. Anthropologist Lagrou (2020) was in communication with her Indigenous Huni Kuin friends in the Brazilian Amazon just before they went into their own self-imposed COVID isolation protocol in early 2020. She was struck with the prescient observation of Huni Kuin shaman Ibã Sales who was certain this new disease belonged to *nisun*, a traditional illness category. *Nisun* in the Huni Kuin language refers to illnesses produced by spiritual revenge of the nonhuman personifications of animal species who are upset at humans for overhunting, disturbing sacred places, sullying certain animal habitats, or disregarding other behavioral norms (see also Read et al., 2010; Shepard, 2004; Vieira & Shepard, 2017). Despite intensive research and public scrutiny, there is still no scientific consensus as to the precise origin of the novel coronavirus pandemic or even whether it emerged from natural zoonotic contagion or from a laboratory leak. However, there seems to be a clear genetic association between the novel coronavirus and closely related pathogens found in bats commonly sold for medicinal purposes in Chinese markets. Ironically, a common ethnic moniker for the Huni Kuin people is Kaxinawa, which means "bat people" in their language, not because they consume bats but because they consider them to have transformative powers. When she mentioned to her Huni Kuin friends that bats might be involved in the origins of the COVID-19 pandemic, they were not surprised: indeed, their shamans had already guessed as much.

As Lagrou (2020) observes:

> The ontologies of these minorities, however, speak a language that contains vital knowledge for the planet today, and that we need to translate urgently into the language of science… New scientific discoveries are moving closer and closer to what Amerindian philosophies have been trying to teach us for some time.

On a recent field trip to the Makushi community of Yupukari in January 2023, coauthor Daly saw how local healers (*taren esak*) similarly responded to COVID-19 using Indigenous epistemologies incorporating microbiological pathogens, spirit projectiles, and shamanic plant remedies. Although many local people had been vaccinated against COVID, Makushi healers emphasized that the impact of the disease was eased locally by the use of traditional "bush medicine." In particular, healers cited the use of "bitter barks" (*mai' pi'pî*), gathered from large trees in the high rainforest (*yu*') and consumed as tea-like infusions. These

infusions combine multiple native with introduced plant substances that have intense sensory properties, including garlic, ginger, and lime. According to villagers, it was Indigenous "high science" (a vernacular term for shamanic wisdom as opposed to Western science and biomedicine), rather than pharmaceutical drugs, vaccines, or social isolation, that protected people against the full impact of this new disease. Local healers understood coronavirus to be a disease (*paran'*) brought by outsiders (*ratiko*), but for which their own traditional remedies gave them more protection than biomedicine in isolation. As evidence, healers contrasted local resilience to the lethal pandemic with the devastation it caused in other parts of the world. In these contrasting examples of Indigenous responses to COVID-19, native practices and epistemologies have been held up alongside Western medicine in a show of cultural resilience and pride.

7. Discussion: Parallax vistas, equivocations, and the emerging bioeconomy

Increasingly, Amazonian biodiversity and the finely tuned socio-ecological systems found in Indigenous territories are under threat from right-wing political movements, rampant resource extractivism, industrial monocultural agriculture, neocolonial ranching, and aggressive development projects. Accelerating deforestation coupled with climate change and extreme oscillations in rainfall are pushing Amazonia toward a "tipping point" that could have catastrophic implications for global climate stability (Lovejoy & Nobre, 2018).

In describing their vision of green development in Brazil through the "Amazon 4.0" bioeconomy initiative, Nobre and Nobre (2019) ask the crucial question: "Is it possible to reconcile the economic development of the Amazon and the conservation of the rainforest?" Bioeconomy is a new approach to sustainable development that has been defined as "an economic activity that is driven by research and innovation in the life sciences and biotechnology, and that is enabled by technological advances in engineering and in computing and information sciences" (Abramovay et al., 2021, p. 9). Abramovay et al. further call attention to the importance of valorizing Indigenous and traditional knowledge and providing economic opportunities for underprivileged forest peoples: "Bioeconomy has the ambition to guide social life towards the regenerative use of the biotic, material, and energy resources on which we all depend. The opportunities that open up for combating poverty and inequality with the sustainable use of forest biodiversity are immense" (ibid., p. 3).

However, given the tremendous cultural, cosmological, moral, and ontological differences between Western and Indigenous economies and forms of knowledge, it is essential that such bioeconomy initiatives approach Indigenous and traditional peoples as more than just sources of useful information or strategic links in the supply chain. Indigenous world views provide us with a template for a profound critical reevaluation of the reductive, objectifying philosophical and moral tenets that tacitly underpin the Western scientific tradition, which is in turn imbedded in the devastating ecological outcomes of capitalism.

Fernandez-Llamazares & Virtanen (2020, p. 24) argue, "the diverse cosmo-centric worldviews placing non-humans at the centre of life together with humans could help to promote innovative ways of operationalising, conceptualising and achieving sustainability from local

to global levels." In bringing scientific and Indigenous perspectives into dialogue and productive tension, we emphasize the need to pay closer attention to Indigenous philosophies of life, vitality, and sustainability (e.g., Black Elk, 2016; Kopenawa & Albert, 2013; Salmón, 2000). From an Indigenous Amazonian perspective, sustainability is a quality of life that ultimately emerges out of the relational dynamics of the multispecies, multinatural shamanic multiverse. As we have pointed out elsewhere (Daly, in press; Daly & Shepard, 2019; Shepard, 2018; Shepard & Daly, 2022), Indigenous lifeworlds are immersed in the vivacious pulse of plant communication, mutualistic interactions, chemosensation, and attendant processes of growth, death, and decay.

To develop the influential idea coined by anthropologist Kohn (2013), if *forests think*, it is precisely through the kinds of embodied, sensorial, and substance-based relationships that we have documented. If such research requires natural scientists to become more conversant in the anthropology of Amazonia (see Sheldrake, 2020), it also requires anthropologists to become more conversant in botany, phytochemistry, and biosemiotics. Indeed, institutions of "Indigenous conservationism" (Cepek, 2011) are fundamentally biocultural, protecting tropical biodiversity and the cultural and linguistic traditions of Indigenous custodians at the same time. However, as Bridgewater & Rotherham (2019) point out, the very term "biocultural," a progressive concept in conservation, still retains the dualistic opposition between the bio- and cultural, even if in a more integrated vision. Numerous authors have called for conservation strategies to respect the rights of Indigenous peoples and recognize their historical role in the sustainable management of Amazonian forests (Blaser, 2009; Mentore, 2011; Brightman & Lewis, 2017; Carneiro da Cunha & Almeida, 2000; Franco-Moraes et al., 2019; Shepard & Daly, 2022).

Cognitive and communication science contributes to contemporary debates around sustainability, biodiversity conservation, and the climate crisis by examining how humans, both individually and collectively, perceive, understand, and respond to environmental phenomena (Kashima, 2020; Ostrom, Gardner, & Walker, 1994; Sewell et al., 2017). However, much of this work has been carried out with European, and specifically, English-speaking subjects, leading several authors to question the broader applicability of these insights to other cultural and linguistic contexts (Blasi, Henrich, Adamou, Kemmerer, & Majid, 2022; Henrich, Heine, & Norenzayan, 2010; Majid et al., 2018). In order to contribute to these debates, we have presented case studies from our own research into Indigenous Amazonian concepts about ecological processes and reviewed contemporary anthropological theories on the topic. Hoping to overcome the impasse between dichotomous thinking about Indigenous versus Western perspectives, we suggest a "parallax" approach to dialogue between Indigenous and scientific knowledge. While acknowledging profound ontological differences, this approach does not rule out the possibility for complementary, or at least mutually illuminating, viewpoints.

Even when Western and Indigenous viewpoints appear contradictory, Furlan et al. (2020, p. 11) suggest that ethnobiologists and other scientists can take advantage of such misunderstandings or "equivocations" (after Viveiros de Castro, 2004b) to ask paradigm-expanding questions: Do we make symmetric efforts to overcome the misunderstandings and at least partially peek into other worlds? What is the value of truth that we assign to these worlds? Such multidirectional, transdisciplinary, and intercultural dialogue is especially important as

prominent scientists and industry leaders develop bioeconomy projects and begin scaling them up as part of "Amazon 4.0." Such initiatives should pay close attention to existing collaborative research and commercial arrangements between Indigenous peoples, scientists, anthropologists, and nonprofit organizations that have been implemented in different parts of Amazonia and beyond (e.g., Abraão et al., 2008; Carneiro da Cunha & Almeida, 2000; Hopkins et al., 2019; Hutukara Association, 2015; Pimenta et al., 2018a, 2018b; Shepard, da Silva, and Brazão 2001). The resulting multinatural exchanges, parallax vistas, and ontological equivocations may prove crucial to global biodiversity and climate stability in the precarious era of the Anthropocene.

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Note

1 Unfortunately, many Evangelical Christian Indigenous communities heeded anti-vaccine disinformation that spread widely through social media in Evangelical circles.

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