Animal medicine

Susana Monsó & Cristian Saborido
Department of Logic, History, and Philosophy of Science
Universidad Nacional de Educación a Distancia

Abstract

The range of animal practices potentially classified as medical varies widely both functionally and mechanistically, and there is no agreed upon definition of medicine that can help determine which cases ought to count as such. In this paper, we argue that all available definitions are fatally flawed and defend our own characterisation of medicine, which incorporates both functional and mechanistic constraints. We apply our definition to the available evidence and determine which animal behaviours show a mere difference of degree with paradigmatic medical practices—and should thus be seen as medicine proper—and which should be excluded from this nomenclature.

1. Introduction

In the spring of 2024, a wild male orangutan named Rakus appeared in news outlets all over the world after he was seen applying chewed-up leaves to an open wound on his face (Laumer et al., 2024). The injury, which was likely the result of a fight with a conspecific and could easily have been infected, instead closed up within a week. The leaves that Rakus had used belonged to the species *Fibraurea tinctoria*, a plant widely used by humans in Southeast Asia for its analgesic, antipyretic, and antidotal properties. By the looks of it, Rakus had been treating his wound.

Scientific interest in the medical practices of nonhuman animals (hereafter, 'animals') has been on the rise since the 1980s, when chimpanzees were first seen using plants to rid themselves of intestinal parasites (Wrangham & Nishida, 1983; Huffman & Seifu, 1989). Since then, many other examples have been reported, from fruit flies who deposit their eggs on food with higher concentrations of ethanol if they detect parasitic wasps in their surroundings (Kacsoh et al., 2013) to rats who eat clay to induce vomit after consuming poison (Nakajima, 2018), ants who amputate the injured legs of nestmates (Frank et al., 2024), and capuchin monkeys who protect themselves from parasites by rubbing their fur with smelly substances (Alfaro et al., 2012).

The range of animal practices potentially classified as medical varies widely both functionally and mechanistically, and there is no agreed upon definition of the term *medicine* that can help determine which cases ought to count as such, or whether in fact any of them should. In this paper, we address this gap in the literature by offering a systematic and well-grounded characterisation of medicine that can help us delineate the relevant phenomena. We argue that medicine takes place when two requirements are met. First, the individual carrying out the behaviour must identify a health problem in her own or another's body, an identification that must be based on normative assumptions about the right and wrong states of the body. This is the cognitive requirement. Second, the individual has to deploy a measure to address the health problem. The deployed solution has to be a measure that would involve a (more or less significant) fitness cost if it were applied to a healthy individual. This is the functional requirement. As we will argue in this article, both requirements are indispensable to speak of medicine in the proper sense of the term.

We develop our argument in four steps. First, we offer a quick review of the relevant empirical evidence, in order to carry out some initial taxonomical distinctions and illuminate where the conceptual issues lie. Afterwards, we present the main definitions of animal medicine that can be found in the empirical literature and identify several problems with them. We then offer our characterisation of medicine and argue as to why we believe it is better suited to single out the relevant phenomena than previous definitions. We end by returning to the empirical evidence and offering a preliminary classification of which animal practices should indeed be considered medical and which shouldn't. Our analysis will show that our definition is simultaneously more expansive and more restrictive than other definitions, and that it serves to better identify which animal practices show a difference of degree with human medicine, and which show a difference of kind.

2. <u>Animal medical practices: the evidence</u>

In this section, we review the extant empirical evidence that points to the presence of medical practices in animal communities. Given that at this stage we haven't introduced any definition of medicine (we will do that in the following two sections), we will simply give an overview of the range of animal behaviours that could be put forward as instances of animal medicine[1] insofar as they involve animals dealing with their own or another's health problem. Some of the cases we will mention are identified as medical practices in the literature while others aren't, but we are bracketing that momentarily. At this stage, we're just looking to give a sense of the broad spectrum of phenomena that we're dealing with here, as well as the kinds of conceptual distinctions that are at stake. In later sections, and especially in

[1] Note that scholars in the debate tend to opt for the term 'medication' rather than 'medicine.' However, we believe that this is due to a bias in favour of considering the use of medicinal substances as paradigmatic cases of animal medical practices. Given that we want to capture a broader range of phenomena, we opt for the term 'medicine', which refers to medical practices more generally and not just those that imply the use of drugs or other medicinal substances.

section 5, we will clarify which cases count as medical according to different definitions, and defend a specific account of which of them should.

When searching for potential instances of medical practices in animal societies, a logical first place to look is at how animals deal with pathogens. Accordingly, one of the very first phenomena to have received scientific attention within this debate is leaf swallowing and bitter-pith chewing in chimpanzees. These two behaviours help chimpanzees to get rid of parasitic worms. Leaf swallowing works in a mechanical way: the chimpanzees fold up and swallow whole the leaves of *Aspilia* plants, which have a rough and hispid texture that serves to dislodge and expel parasitic worms from the intestinal tract (Huffman et al., 1996). Bitter-pith chewing works chemically: the chimpanzees chew on the pith of *Vernonia amygdalina* plants and swallow the bitter juices, which have antiparasitic properties (Huffman et al., 1993).

Since those initial reports on chimpanzees, other studies have found animals ingesting substances with medicinal properties in response to pathological states of the body. Alaskan brown bears ingest leaves that help to expel tapeworms before going into hibernation, as do Canadian snow geese before their big migration south (Huffman, 1997). Infected bumble bees prefer to ingest nectar laced with nicotine, which lowers their parasite load (Baracchi et al., 2015). Rats, who are physiologically incapable of vomiting, will ingest clay after having consumed toxic substances, which helps them alleviate nausea (Nakajima, 2018).

However, ingesting medicinal substances in response to disease doesn't exhaust the range of potential medical practices in animals. For starters, we can make a distinction between therapeutic medication and prophylactic medication. While the former is a response to a diseased state of the body, the latter serves as a precaution. Readers with companion dogs will have seen them readily consuming grass, which appears to be in most cases a prophylactic behaviour aimed at clearing out potential parasites from the intestinal tract before they actually feel sick (Hart, 2011; Sueda et al., 2008). Ants will increase their intake of reactive oxygen species when exposed to, but not yet infected by, a fungus (Bos et al., 2015). Asian elephants have been reported to consume large quantities of *Entada schefferi* before embarking on a long journey, which may give them stamina but also protect them from pain (Huffman, 2003). Hamadryas baboons that live in areas with a higher presence of parasites will tend to eat more berries with antiparasitic properties (de Roode & Huffman, 2024). Western lowland gorillas regularly consume bark from plant species with antioxidant and antimicrobial properties, and show asymptomatic cases of *E. coli* presumably as a result (Yinda et al., 2024).

The inclusion of prophylaxis as a medical practice raises the worry of where to draw the line between medication and food consumption. Many of the foods that we eat for nutritional purposes have indirect medical benefits. In fact, both medication and food consumption are mechanisms that are conducive to homeostasis and involve the ingestion of substances that further this end. In response to this worry, some authors have argued that the dose of the ingested substance may often be key. For example, caterpillars of the species *Grammia incorrupta* increase their consumption of pyrrolizidine alkaloids when they are infected by parasites. While this is a normal part of their diet that serves prophylactic purposes, the increased dose has therapeutic effects (Singer et al., 2009). Many have also argued that there has to be a fitness cost for healthy individuals consuming that same substance, otherwise it's not medication but simply a diet choice (Singer et al., 2009; Abbott, 2014; Bos et al., 2015; de Roode et al., 2013; Lefèvre et al., 2010; Roode & Huffman, 2024).

Ingestion is not the only way that an animal may come into contact with a medicinal substance. We began this paper mentioning the case of the orangutan Rakus, who tended to the wound on his face by smearing *Fibraurea tinctoria* pulp on it, a process that helped his injury heal without infection (Laumer et al., 2024). In fact, absorption, topical application, and proximity may all help an animal benefit from the curative or prophylactic properties of a substance. Red-fronted lemurs anoint their tail and perianal area with millipedes, which seems to protect them from nematode infections (Peckre et al., 2018). Capuchin monkeys will rub their fur with ants to eliminate parasites, and those living in urban areas may forage for different kinds of objects to self-anoint with, such as wet wipes, hot peppers, liquid soap, cologne, onion, cigarettes, or bleach (Alfaro et al., 2012). Some species incorporate into their nests substances that inhibit bacterial and fungal growth. Wood ants (Castella et al., 2008) and honeybees (Simone et al., 2009), for instance, forage for resin when building their colonies and add it to the nests. Dusky-footed wood rats incorporate bay leaves into their nests, which gives them protection against parasites (Hemmes et al., 2002). And urban species of birds such as house sparrows and finches have been seen to use cigarette butts as part of their nest-building materials, which serves the same purpose (Suárez-Rodríguez et al., 2013).

Animals may also engage in other behaviours that don't involve medicinal substances but can be either therapeutic or prophylactic. For instance, animals often regularly change where they eat or sleep, they may avoid eating faeces or feeding on the remains of dead conspecifics, or develop an aversion to foods or tastes associated with ill-being (Hart, 2011). Rats develop an aversion to nutritionally deficient diets (Rozin, 1976) and pay attention when conspecifics are eating something unusual (Galef, 1993). Red-winged blackbirds develop aversions to specific kinds of foods if they see conspecifics falling ill after eating them (Mason & Reidinger, 1982). Some insects engage in corpse management, burying nestmates or extracting their remains from the colony (Sun & Zhou, 2013). All of these behaviours have prophylactic advantages, serving to protect the animals from coming into contact with pathogens. With respect to therapeutic behaviours, apart from interacting with medicinal substances, the animal may stop eating, sleep more than usual, avoid using an injured limb, lick her wounds, and so on, all of which may aid the healing process (Hart, 2011). And in a rather extreme example of a curative behaviour that doesn't involve medicinal substances, pairs of injured comb jellies will heal themselves by fusing into one (Jokura et al., 2024).

All the mentioned behaviours are instances of what is often termed *self-medication*, that is, medical practices directed at improving one's own health. However, there are some instances of animals engaging in medical practices that improve others' fitness, either therapeutically or prophylactically—

what's known as *allomedication* (de Roode & Huffman, 2024). The others at which these behaviours are directed may be kin. For instance, fruit flies protect their offspring by opting to lay their eggs in food with high levels of alcohol if they visually detect wasps in the environment. This way, they protect their larvae from infection by parasitic wasp larvae, who have a lower alcohol tolerance (Kacsoh et al., 2013). Monarch butterflies that are infected with parasites prefer to oviposit on toxic species of milkweed, on which their offspring will feed and, as a result, experience a reduced parasite load (Lefèvre et al., 2010). And some of the most impressive therapeutic behaviours come from eusocial insects, who will often treat their nestmates, with whom they are related. Ants of the species *Megaponera analis* carry wounded nestmates back to the colony when they raid termite nests, and ants who have a termite attached to them have it removed and wounds are groomed and treated with antibacterial secretions (Frank et al., 2017; Frank et al., 2023). Ant queens of the species *Lasius niger* feed on their sick larvae to stop the infection from spreading (Bizzell & Pull, 2024). And even more impressively, ants of the species *Camponotus floridanus* perform amputations of their nestmates' legs when these are injured (Frank et al., 2024).

Occasionally, animals will also engage in care behaviours directed at non-kin in what could be considered medical contexts. Many social species engage in mutual grooming, a behaviour that serves to get rid of parasites and is often not directed at kin. We also see care behaviour directed at disabled, injured, or dying conspecifics in many social species, such as elephants (Bates et al., 2008; Douglas-Hamilton et al., 2006) or dolphins (Park et al., 2012). Chimpanzees will occasionally groom, lick, and even use leaves as tools to clean the wounds of conspecifics (Clark et al., 2021). And support during parturition has been observed in black-and-white snub-nosed monkeys (Ding et al., 2013), white-headed langurs (Pan et al., 2014), and bonobos (Demuru et al., 2018).

3. The problem(s) with present definitions

In this section, we give a summary of how animal medicine has been defined in the literature and point out the commonalities between different characterisations and the problems that we see in them. The definitions that we will consider all come from the empirical literature. The philosophical literature on the definition of medicine has until now been strictly concerned with the demarcation of 'real', 'good', or 'scientific' human medicine and how to distinguish it from 'false', 'bad', or 'pseudo' human medicine (see, for instance, Solomon 2015; Broadbent 2019; Fuller 2024). Given that the criteria given to distinguish real from false medicine were all designed with the human context in mind, the resulting characterisations are too anthropocentric to be of use for present purposes. For instance, real medicine is typically taken to be that which takes place within certain established institutions, which will obviously be lacking in the case of animals. The definitions coming from the empirical literature, instead, aim to capture the phenomenon as it might manifest in nonhuman taxa. For that reason, we believe it is more fitting to take them as our starting point.

One of the first definitions that can be found in the literature comes from Clayton and Wolfe (1993):

> Self-medication can be classified into four categories according to the mode of contact: ingestion, absorption, topical application and proximity. The adaptiveness of each of these categories can be determined by jointly testing the following three hypotheses: (1) the medicinal substance is deliberately contacted by the medicator; (2) the substance is detrimental to one or more parasites when contacted (namely viruses, fungi, bacteria, protozoa, helminths and/or arthropods); and (3) the detrimental effect on parasites leads to an increase in host fitness. (p. 60)

Four things are noteworthy about this definition. First, it only recognises the possibility of self-medication, thus excluding allomedication. Second, it requires the involvement of a medicinal substance of some sort, and therefore excludes other kinds of medical treatment. Third, it doesn't set any mechanistic constraints, save for the fact that the medicinal substance must be "deliberately contacted", presumably to exclude accidental self-medication. And last, it requires the treatment to be successful, meaning that it must be detrimental to the pathogen and increase the animal's fitness. Though this last requirement presumably was introduced with the function of testing for the adaptiveness of an animal's behaviour, it was retained in all later definitions while losing this function.

Clayton and Wolfe's (1993) definition set the tone for many of the definitions that were to follow, but it's missing a crucial element that was introduced by Singer et al. (2009):

> Our results demonstrate three essential components of self-medication predicted by adaptive plasticity theory: 1) self-medication behavior improves fitness of animals infected by parasites; 2) *self-medication behavior decreases fitness in uninfected animals*; and 3) infection induces self-medication behavior. (pp. 4–5, our emphasis)

This definition introduces the idea that medical behaviour must be maladaptive when applied to healthy individuals. The idea of a fitness cost for uninfected animals, as we saw in the previous section, allows medication to be distinguished from general health maintenance, such as the consumption of food or water, and all definitions of animal medicine that followed incorporated this criterion. Other than that, Singer et al.'s (2009) definition is very close to Clayton and Woolfe's (1993).

Additional definitions were provided by Lefèvre et al. (2010), de Roode et al. (2013), and Bos et al. (2015), and it's worth pointing out their commonalities and differences with these initial definitions. In contrast to them, Lefèvre et al. allow for the medication of kin, as do de Roode et al. In line with previous definitions, Bos et al. only recognise self-medication. Lefèvre et al. don't require the involvement of a medicinal substance, but de Roode et al. and Bos et al. do. Lefèvre et al. pose no mechanistic constraints, while de Roode et al. add the specification that the behaviour must be initiated by parasitic infection and Bos et al. require the use of the substance to be deliberate. All three definitions specify that the treatment must be successful and that there must be a fitness cost for healthy individuals. And lastly, de Roode et al. introduce a new criterion that will not be picked up by later papers, namely, that the practice has to occur in an ecologically valid setting (to rule out the scientific relevance of findings in the lab under very artificial conditions).

The final definition we want to consider is de Roode and Huffman's (2024), which can be thought of as a consensus definition, insofar as it was published in a review by two of the biggest names in the field, who hadn't co-authored previously:

> For therapeutic medication, observational studies need to fulfill four conditions: (i) the animal shows disease symptoms (or other health issues); (ii) the animal seeks out a particular medicinal substance specifically (rather than using it randomly); (iii) using the substance reduces infection, alleviates disease symptoms, or increases health; and (iv) the substance is costly (and/or not sensed to be palatable) to the animal and therefore avoided when not ill. (p. R809)

Like other definitions before, this definition only applies to self-medication (though in the paper they acknowledge the existence of allomedication), it requires the deployment of a medicinal substance, and needs the treatment to be successful. It also incorporates the need for a cost for healthy individuals, but makes this broader than a fitness cost, allowing for the possibility of a mere experiential cost (unpalatability). There are no mechanistic constraints, save for the condition that the substance ought to be sought out specifically instead of randomly.

To sum up, then: the available definitions tend to only recognise self-medication or kin medication and tend to require the involvement of a medicinal substance. All of them require the treatment to be successful in healing the animal to some degree in order for the behaviour to be a case of medicine, and all of them (after Singer et al., 2009) require a fitness cost if the same treatment were to be applied to healthy individuals. In addition, the definitions make very thin specifications on the causal mechanisms that must be involved for a behaviour to qualify as medical. These specifications, in turn, appear to be just meant to exclude accidental medication (for instance, an animal randomly feeding on a plant that happens to have medicinal properties).

The definitions that can be found in the empirical literature are perfectly adequate for some purposes. For instance, if we wanted to find animal behaviours with the potential to uncover new medicinal plants, these definitions would all work, since they would point us in the direction of substances with therapeutic properties. However, if we are concerned, as is our case, with the conceptual endeavour of delineating the criteria that must be met by a behaviour for it to count as a *medical* practice, these definitions are all lacking. In what follows, we defend why this is so.

For starters, one of the desiderata that we would want a definition of animal medicine to fulfil is for it to encompass common denominators of medicine in general, thus allowing it to be applicable to paradigmatic examples of medicine, such as that carried out by human doctors in hospitals, while excluding contingent characteristics of specifically human medicine, such as the fact that it is typically carried out within an institution. If we compare the available definitions with human practices, we can easily see how they give rise to the counterintuitive result that much of what we consider prototypically medical would not be categorised as such. Indeed, a vast majority of medical practices in human societies are not directed at the self or at kin, but at strangers that doctors and nurses routinely treat. Many of our medical practices, such as physiotherapy or psychotherapy, don't involve medicinal substances. And a significant proportion of the treatments dispensed at hospitals and medical centres are not successful, leaving the patient in the same or in worse condition than she was initially, and in some cases even killing her. While we may speak of erred diagnoses, failed treatments, or even negligence, we still consider them to be medical practices.

Moreover, these definitions incorporate such thin or non-existent mechanistic constraints that they ultimately qualify as functionalist. Functionalist approaches to animal medicine, while having the potential to uncover astounding adaptations, are not without significant limitations. One key shortcoming is their neglect of the cognitive mechanisms underlying these behaviours. This oversight does not give us the tools to distinguish between stereotyped adaptations and behaviours that are guided by the animal's cognition. From a functionalist perspective, any behaviour leading to improved health is categorised as medicine. This lumps together rational, deliberate behaviours, such as those that might be exemplified by the case of Rakus we saw in the introduction, with innate adaptive responses, such as those observed in insects. This, in turn, risks dismissing the importance of deliberate problem-solving, intentionality, or learned strategies, which are hallmarks of prototypical medical behaviours.

Another critical flaw in a strictly functionalist approach is its inability to accommodate the possibility of errors, failures, or insufficient measures in medical practices. Functionalist definitions rely on health improvement as the defining outcome of a medical practice. This restricts the concept of medicine to actions that are invariably successful, excluding measures that aim at healing but do not fully succeed. However, it seems reasonable to classify merely partially effective or entirely unsuccessful attempts at healing as medical. For instance, if Rakus, despite his efforts, did not manage to avoid infection, would his attempts to heal himself no longer be considered medical? Such a conclusion seems counterintuitive and unhelpful, especially given that, as we have already mentioned, a significant proportion of treatments delivered in human hospitals fail at healing the patient. If we were to adopt a strictly functionalist definition of medicine, much of what occurs in human medical contexts would be deemed non-medical. Thus, allowing for the possibility of errors or inadequacies in medical practices is essential for developing a comprehensive and useful definition of medicine. This is true not only for human medicine but also for understanding analogous behaviours in animals. A strictly functionalist approach, by focusing solely on successful outcomes, fails to address these dimensions, thereby limiting its explanatory power and practical applicability. In the following section, we offer an alternative approach.

4. Redefining (animal) medicine

In this section, we argue that it is necessary to complement the functionalist approach with one that singles out the cognitive mechanisms that allow the identification of certain conditions as medical problems and trigger the implementation of concrete measures to address them. In particular, we will defend the following general definition of medicine:

Medicine can be understood as a practice that satisfies two essential requirements:

- **The cognitive requirement**: This entails the identification of a health problem, defined as a non-normative state of the body. Meeting this requirement involves both conscious awareness of the issue and normative assumptions about the appropriate or inappropriate states of the body.
- **The functional requirement**: This involves the implementation of measures that address the identified health problem. These measures must be directed at individuals experiencing the problem (i.e., the sick) and entail a fitness cost for healthy individuals if applied to them in the same manner or to the same extent.

These two requirements—the cognitive and the functional—form the foundation of a comprehensive understanding of medicine, one that can allow us to identify medical practices in both humans and animals. In the following subsections, these requirements will be explored in detail, highlighting their significance, implications, and the ways in which they distinguish medical practices from other behaviours. Note, however, that we're separating them for analytical purposes, but in reality, as will become clear from our analysis, the cognitive and functional aspects of a medical practice are intertwined, interacting and influencing each other.

4.1. The cognitive requirement

The first requirement that must be met by a medical agent is the identification of a health problem that is understood to need a solution. A way in which this cognitive requirement might be instantiated in animal minds is through the presence of what Danón (2024) terms *instrumental ought-thoughts*, which are "first-order representations of non-actual ideal situations [that] represent a course of action as the one to be taken" (p. 6). Though Danón devised instrumental ought-thoughts as a way of making sense of the normative character of chimpanzee tool-use behaviour, we believe that this notion can be fruitfully applied in this context too. According to Danón, three conditions must be met for a mental representation to qualify as an instrumental ought-thought:

1. “animals who possess such thoughts must be able to represent not only what is the case but also what ought to be the case and use these representations as standards to guide their behavior”
2. “they must show a tendency to comply with what these representations prescribe or recommend while still being capable of doing otherwise”
3. “they must be able to detect when their behavior fails to conform to what their ought-thoughts prescribe or recommend and correct [it[2]] accordingly” (Ibid.)

Applied to our present interest, the first condition refers to the ability of an agent, whether human or nonhuman, to mentally represent an ideal or improved state of health that is not present in the current reality but is envisioned as a desirable goal. This representation will guide the selection of means and actions necessary to achieve it. Thus, our definition of medicine does not require the ability to formulate a theoretical definition of health but rather the capacity to grasp the contrast between a current state—characterised by disease, injury, or infection—and a non-actual state of healing, absence of discomfort, or restoration of normal functioning. This recognition provides a normative framework where health is perceived as a goal: a state that ought to be achieved. This capacity for anticipation allows the agent to project a desired state where the disease or discomfort has been resolved or mitigated, using this projection as a reference point for her actions.

The second condition implies that the current state (such as being ill, experiencing pain, or dealing with parasites) is perceived as mismatched or discrepant with the ideal state of health (being free of disease or discomfort). This gap creates the motivation for action, guiding the agent to select means that address the discrepancy. Importantly, the process is not impulsive; rather, it is normatively driven by the recognition that the current state deviates from how things ought to be. For this normativity to be in place, as Danón argues, we need the agent to be capable of ignoring her motivation for action. If the individual cannot help but act on her motivation, then she’s not being guided by an understanding of how things ought to be, but rather carrying out a behaviour over which she has no control, such as a fixed action pattern. Instead, the instrumental ought-thoughts involved in a medical practice give the agent a *reason* to carry out a particular behaviour, but the agent can choose to do otherwise.

The third condition implies the ability to evaluate the effectiveness of the chosen means in reducing the gap between the current and the ideal or improved state. If the means prove ineffective, or the ideal state has not been reached to a sufficient degree, the motivation to close the gap between current and ideal state reemerges. The agent must in principle be capable of adjusting her approach or

[2] Danón’s paper says “them” rather than “it”, but this is clearly a typo, since this condition refers to the capacity to correct the behaviour and not the thoughts. However, the animal may also form an incorrect ought-thought that prescribes the wrong behaviour for the intended goal, and should be in principle also capable of correcting her thoughts, something that, according to this same author, does not require metacognition (Danón & Kalpokas, 2023). In what follows, we will take this third condition to refer indistinctly to the animal’s capacity to correct her behaviour or her ought-thoughts.

choosing an alternative means, thus demonstrating a capacity for error correction. This new motivation, as before, must also be ignorable. Medical agents therefore do not merely react automatically to stimuli but evaluate their circumstances and actively select means to achieve desired ends.

A hypothetical example might help to make this clearer. We can imagine an individual, let's call him Mikel, who is experiencing a stomachache. Mikel can distinguish between his current state of discomfort and an ideal state in which his stomach doesn't hurt. This creates a motivation to eat some of the leaves that he has learned can alleviate stomachaches. Mikel decides to try some of those leaves. If they get rid of the pain, Mikel will forget about it entirely. If they're not sufficiently effective, the motivation to do something about the pain will reappear, and Mikel might decide to eat some more of those leaves or try out an alternative strategy, such as rubbing his belly. This framework can also accommodate other-directed medical practices. The one experiencing the stomachache might not be Mikel, but his friend Aquiles, and yet Aquiles's stomachache might also be perceived by Mikel as something that deviates from an ideal situation in which his friend is free from pain. Mikel might then decide to offer Aquiles some of the therapeutic leaves. In either scenario, Mikel can always choose to behave differently from how he actually does.

4.2. The functional requirement

Implicit in our analysis of the cognitive requirement was the idea that a medical practice involves the deployment of measures to tackle the current non-ideal state. This is the functional requirement: simply identifying a health problem is not enough—there would be no medicine if individuals just identified certain conditions as pathological. It is necessary to carry out concrete behaviours to address these conditions. Medicine thus involves the implementation of measures to address an identified health problem. However, this functional requirement differs significantly from the functionalism present in the definitions we saw in section 3. We will not argue that a behaviour is medical when it *solves* a medical problem, but that it is medical if it is *intended to address* a medical problem. This nuance is important because it implies the introduction of intentionality and purpose into medical behaviour, while also allowing for the possibility of errors.

The cognitive requirement implied that medical behaviours are the results of a process of rationally responding to reasons[3], but this does not mean that these responses must be univocal for each specific problem. Medical practices are (often dysfunctional) attempts to attack diseases and other ailments. Different medical practices can be carried out to address the same medical problem, and these practices often conflict with each other. An important implication of the approach we're defending here

[3] Though animals have traditionally been thought of as non-rational, there is now a wealth of empirical evidence and philosophical arguments to support the view that animals can act and form beliefs in a way that rationally responds to reasons; see Melis & Monsó (2024) for an overview. Our framework only requires attributing to animals what Melis & Monsó term 'unreflective' responsiveness to reasons, a capacity that they deem to be widespread across species.

is that it puts the focus on the meaning that a physical or mental condition has for the individuals that interpret and address these conditions. This thus opens the way to incorporating a radical pluralism—in Kukla's (2022) sense—with respect to disease categorisations and medical practices:

> Different cultures have different medical institutions that fit together only imperfectly and sometimes actively conflict […]. Moreover, these different institutions sometimes classify and count diseases quite differently from one another […]. Even within one region, it is not at all clear that there is one unified medical institution for the very rich and the very poor, and so forth. Some diseases are medicalized within some medical institutions and not others. Hence medicalizing a condition does not mean inserting it into one unified institution, but into a messy web of institutions. (p. 10)

Human medicine encompasses a variety of practices that may differ in form, approach, and even efficacy. As Kukla highlights, our medical practices exist within a "messy web" of institutions, classifications, and conflicting approaches, suggesting that there is no singular, universally optimal medical practice.

This point may apply not only to human medicine but also to the medical behaviours observed in nonhuman animals. In the case of animals, we may see a variety of techniques to deal with the same issue, from ignoring it if the individual does not identify it as a problem to using different means to address it. Different species or even populations within a species may develop unique medical practices tailored to their ecological and social contexts, just as human societies develop diverse medical traditions. In addition, there may be differences across individuals of the same population, and even across the lifespan of a single individual, who may acquire more refined techniques to deal with her health problems as she ages. The shared theme is that medicine, whether human or nonhuman, is not a monolithic institution but a pluralistic, context-dependent phenomenon.

This insight aligns closely with the idea that not all medical practices—whether in humans or in animals—must be optimal, successful, or even beneficial to qualify as medicine. While some animals might engage in highly effective self-medication practices (e.g., chimpanzees consuming antiparasitic plants), others may adopt less effective or even detrimental strategies due to lack of experience or knowledge, environmental constraints, or evolutionary trade-offs. These 'bad medicine' examples, such as the ingestion of ineffective or toxic substances, illustrate that the distinction between medical and non-medical behaviour does not rest on success or failure but on the presence or otherwise of an intention to address a specific health issue.

However, not all behaviours in response to a health issue would qualify as medical. The action taken to address the problem must be a measure that would reduce fitness if applied to healthy individuals. As we saw, this is a condition that is present in all definitions of animal medicine in the empirical literature, and we think that it is worth preserving, as it allows us to distinguish medical interventions from other health-promoting behaviours. For an action to qualify as medicine, it must address a specific health issue, such as a disease or infection, and it must carry a fitness cost, meaning that, in the case of a successful treatment, it would give rise to a trade-off: the intervention becomes beneficial only because of the pathological condition it targets. For instance, the ingestion of bitter, toxic plants to combat intestinal parasites constitutes a medical intervention. In healthy individuals, consuming these plants would likely have negative effects, such as reduced energy availability or toxicity, thereby lowering overall fitness. However, in diseased individuals, the same action provides a net benefit by mitigating the condition's harmful effects.[4]

This criterion helps differentiate medicine from behaviours like hygiene, regular exercise, or a balanced diet, which contribute to overall health and fitness regardless of the presence of disease. While these practices reduce the likelihood of illness and promote well-being, they do not entail the specific trade-offs characteristic of successful medical interventions. Instead, they serve as preventive measures or baseline behaviours for maintaining health, rather than being targeted responses to pathological conditions. This criterion also serves to differentiate medical practices from responses to non-ideal states of the body that are not pathological. For instance, an animal may feel hunger and this can give rise to instrumental ought-thoughts about the need to alleviate this state, which in turn motivate her to eat. But we wouldn't consider this a medical practice because eating, under normal conditions, is not maladaptive.

While our functional requirement entails the need for a fitness cost, the actual costs for healthy individuals performing that same behaviour may vary widely in magnitude. Some of the practices that animals engage in to deal with health problems would be direly maladaptive if applied to healthy individuals. An example of this is the amputation of injured limbs that we see in some species of ants (Frank et al., 2024). Not only might[5] this be very painful for the treated ant, but she must also relearn how to walk (Ibid.), which would imply a big fitness cost if she were entirely healthy. In contrast, dabbing at one's wounds with leaves, like chimpanzees have been seen to do (Clark et al., 2021), entails a very marginal fitness cost, but would still be maladaptive (in the sense of having no survival value and providing no evolutionary advantage) if the individual were entirely healthy. At the same time, any behaviour ends up being maladaptive if carried out to a sufficient degree, so following Abbott (2014) we add the caveat that the fitness cost should occur if the treatment were applied to a healthy individual *in the same manner or to the same extent* as it is applied to the non-healthy one.

[4] Note that the net benefit is not a *requirement* of our approach, but just something that will happen if the treatment is successful. We only require medical interventions to entail a fitness cost for healthy individuals—in the case of diseased individuals, that same treatment may be beneficial or not depending on its effectiveness.

[5] The jury is still out on whether insects can feel pain. For an overview of the debate, see Birch (2020).

5. The evidence revisited

Having introduced and defended our definition of (animal) medicine, in this section we return to the evidence that we presented in section 2 and apply our framework to it. As will become apparent, our definition is simultaneously more restrictive and more expansive than the definitions that can be found in the empirical literature. This means that, while some animal practices will count as clear cases of medicine according to both frameworks, our definition singles out as borderline or non-medical some of what the empirical literature considers medical. At the same time, our definition covers some animal practices that the empirical literature doesn't even consider as potential instances of animal medicine. In what follows, we explore each of these cases. Given that the study of animal medicine is still unfolding, and that our definition requires the presence of mental states that have not been directly tested for, all the empirical claims that we make in this section should be taken with a grain of salt.

5.1. Cases that count as medical in both frameworks

Great apes are the taxon that best exemplify the overlap of our definition with previous characterisations of medicine. As we saw, it was the observation of chimpanzees self-medicating that kicked off the whole field of study, and to this day great apes are generally considered a paradigmatic example of animals who engage in medical practices. We believe that there are also good reasons to think that they exercise medicine in our sense of the term. This is because there is evidence that they satisfy both of our requirements: the functional and the cognitive one.

The medicinal practices that we see in great apes seem firstly to satisfy the functional requirement. Bitter-pith chewing and leaf swallowing appear to happen only in the presence of parasitic infections. At the same time, they would have a fitness cost for healthy individuals, since they are time-consuming practices—chimpanzees often have to go out of their way to find the right plants (Huffman, 1997), and stripping the bark off the pith and peeling the leaves takes time (Huffman & Seifu, 1989; Freymann et al., 2024). There also doesn't seem to be any nutritional benefit to the consumption of these substances—the pith's juices have negligible nutritional value (de Roode et al., 2013), and the swallowed leaves are expelled without being digested (Wrangham & Nishida, 1983). The cleaning of wounds with leaves that has been seen in chimpanzees also seems to fulfil the functional requirement, insofar as chimpanzees are not reported to rub their own or others' skin with leaves in the absence of wounds and indeed it would not have any survival value to do so. In the case of Rakus, he is reported to have spent a considerable amount of time applying the chewed-up pulp to his wound (Laumer et al., 2024, p. 4), which would have been maladaptive if there had been nothing wrong with his skin.

Demonstrating that these animals' behaviour also fulfils the cognitive requirement is a trickier business, especially given that the research until now has not been looking for indications of specific mental states. However, we do have some evidence that these behaviours are under cognitive control.

One key piece of evidence is precisely their rarity. This is most obvious in the case of Rakus. As pointed out, his is the only known case of an orangutan treating their wounds with a medical substance. This suggests that the behaviour emerged through individual innovation. In fact, Rakus is reported in the paper to have had a wound inside his mouth at the time, as well as the one on his cheek (Ibid.). The leaves on which he was feeding, in turn, have potent analgesic properties (Ibid., p. 5), so it's not outlandish to suppose that his mouth went numb as he fed on them, and for that reason he decided to try applying the pulp to the wound on his cheek in an attempt to ease his pain.

In the case of leaf-assisted wound-cleaning, a five-year study reported one hundred sightings of wild chimpanzees with wounds, out of which twenty-nine exhibited self-grooming of wounds, and only thirteen of which used leaves. A mere four cases out of these one hundred revealed other-directed wound care (Clark et al., 2021). The infrequency of these practices is an indication that these are not stereotyped behaviours, but rather deliberate responses to wounds that these specific individuals see as problems, and that either not all chimpanzees care about their own and others' wounds or that not all of them have the requisite knowledge to deal with them.

As for bitter-pith chewing and leaf swallowing, these are much more frequent practices, but we have some evidence that these are not innate behaviours, but rather learned cultural traditions. For one, this is a behaviour that occurs in several populations of chimpanzees, but not all of them, and different populations use different, though functionally similar, species of plant (Huffman, 1997). Experiments on captive chimpanzees have shown that they don't initially know how to swallow leaves of the sort that are used by their wild counterparts to clean out their guts. In fact, they tend to have an almost phobic reaction to their rough texture. Out of all the chimpanzees presented with the leaves, only two spontaneously folded them and swallowed them whole. Several other chimpanzees then started copying this behaviour, which suggests that in the wild the behaviour probably emerged from a mix of individual innovation and social learning (Huffman & Hirata, 2004). In the case of pith chewing, wild infants are occasionally seen chewing on piths that their sick mothers have used, but healthy adults never do it. In addition, in at least one reported case, a mother prevented her healthy infant from picking up a discarded pith that a sick adult had left behind (Huffman, 1997), hinting again at social learning.

5.2. Cases that count as medical in other frameworks and non-medical in ours

The group of cases over which there is the starkest contrast between our framework and previous ones is the therapeutic behaviour of insects. These behaviours clearly satisfy the functional requirement, since they take place exclusively in the presence of a non-healthy state of the body and the measures taken (amputation of limbs, ovipositing on toxic plants, etc.) imply a trade-off, being beneficial only because there is a health problem to begin with. However, all signs point to the behaviours not being under cognitive control, which makes them both very predictable and very rigid. For instance, fruit flies only lay eggs on fruit with high ethanol concentrations if they visually detect parasitic wasps, but not if the detection happens through other sensory modalities (Kacsoh et al., 2013). Ants who rescue injured nestmates do so only if they're found on the hunting ground or the return journey, but not on the way there. Healthy individuals sprayed with the rescue pheromone will also be taken back to the nest (Frank et al., 2017). The amputation of limbs only occurs when the injury is at the level of the femur. And in stark contrast to the case of wound care in chimpanzees, the vast majority of wounded individuals that fulfil this condition have their legs amputated, and the ants who carry out the behaviour follow a very rigid behavioural sequence (Frank et al., 2024). Thus, while impressive, these behaviours are not solutions that individuals implement to solve what they perceive as problems, but rather stereotyped innate responses to very concrete stimuli. For this reason, we think it more appropriate to speak here of therapeutic adaptations, instead of medicine proper.

Another group of cases that is excluded from our definition is prophylaxis. Though prophylactic behaviours are not covered by the definitions of medicine that can be found in the literature, they are often cited as examples of animal medicine (Lozano, 1998; Vitazkova et al., 2001; Castella et al., 2008; Hart, 2011; de Roode et al., 2013; Kacsoh et al., 2013; Abbott, 2014; Bos et al., 2015; Frank et al., 2018; Peckre et al., 2018; Neco et al., 2019; de Roode & Huffman, 2024; Freymann et al., 2024; Laumer et al., 2024). Our characterisation of medicine has the implication that prophylaxis is excluded, since it doesn't fulfil the functional or the cognitive requirement, given that there's no actual physical problem that needs solving. Behaviours like corpse-management in eusocial insects, avoidance of rotting food in many mammals, and so on, are better seen as prophylactic adaptations, but not medicine.

5.3. Cases that count as medical in other frameworks and borderline in ours

Some therapeutic behaviours in animals don't appear under as much cognitive control as the great apes', but don't seem to be as stereotyped as the insects'. These are cases like monkeys who anoint themselves with different antiparasitic substances, rats who eat clay to deal with nausea, or domestic animals who purge themselves by eating grass. These behaviours satisfy the functional requirement—they are responses to health problems that involve a fitness cost such as skin irritation or vomiting—but they don't seem to satisfy the cognitive requirement. While the data on these practices is scarce, they appear to be homogeneous across each species, which suggests that they are the result of innate predispositions rather than learned behaviours, and thus don't seem to involve much, if any, understanding of the situation by the animal. Still, we label them as 'borderline' rather than 'non-medical' because we believe that these animals are cognitively complex enough that throughout their lives they might realise that these substances alleviate their symptoms, and eventually seek them out more deliberately.

The type of learning required for animals to reach this understanding is not very complex at all, simply a form of associative learning, and there are reasons to think it will be widespread. For instance, in the case of ingestion, animals will generally be predisposed to monitor how different substances affect their body, in order to avoid toxic substances (Rozin, 1976; Galef, 1990; Huffman, 1997; Villalba et al., 2006; Moore et al., 2013). This learning capacity must be sufficiently prevalent for animals who signal toxicity through bright colours or who mimic the appearance of toxic species to have evolved countless times. The ability to learn that something cures you is the same type of learning involved in avoiding food that upsets your stomach, but in reverse. And given the right circumstances, animals appear to learn this easily. For instance, experiments have shown that sheep who are given medicinal substances after eating something toxic will learn to associate each substance with the recovery from each particular toxin (Villalba et al., 2006). We propose, then, that the borderline behaviour of animals can become medical the moment this learning has occurred and a treatment is deliberately sought out to alleviate a health problem.

5.4. Cases that count as non-medical in other frameworks and medical in ours

There are, lastly, some animal practices that our framework would count as medical but are not considered in the empirical literature. One example is the care behaviour displayed towards individuals who are disabled, dying, or dead. These behaviours are relatively rare, and they seem to fulfil the functional and cognitive requirements to count as medical. To give but one example, Park et al. (2012) documented a group of dolphins helping a dying conspecific breathe by making a raft-like formation with their bodies to keep her afloat. If the dolphin had been healthy and able to swim properly, it would have been maladaptive for her freedom of movement to be constrained that way. The behaviour only made sense because she was ill, thus fulfiling the functional requirement. At the same time, it is an extremely unusual practice that showed that the dolphins understood her situation and were displaying a form of care that adapted to her bodily needs, thus fulfiling the cognitive requirement. Something similar may be said about the cases of support during parturition, where the helper is usually a multiparous female who appears to understand the needs of the parturient (Ding et al., 2013; Pan et al., 2014).

A final group of practices that is excluded from previous definitions but covered by ours is that of bad medicine. Here we must admit to a lack of evidence of animals treating their ailments in a misguided way, but we believe this may be due to a skewed attention on the scientists' part, since all previous definitions require a treatment to be successful for it to count as medicine. The only potential example we have found is that of chimpanzees rubbing their own and others' wounds with insects, which has been observed in a population in Loango national park (Mascaro et al., 2022). The authors claim that it "may" be a case of animal medicine, but that "further systematic research is needed to elucidate the efficacy of the treatment associated with an improvement in healing of wounds" (p. R113). Within our framework, the efficacy of the treatment is not required, but instead we would need evidence that the chimpanzees perceive the insects as a (misguided) solution to the problem that is a wound. While we don't currently have such evidence, we do know that chimpanzees are emotionally affected by images of hurt conspecifics (Sato et al., 2019) and they have been seen to dismantle snares in the wild (Ohashi & Matsuzawa, 2011), in addition to all the evidence of (tool-assisted) wound care in this species. So, if the insects applied don't aid the healing process, this behaviour might still be an instance of medicine in chimpanzees, albeit of the bad sort.

6. **Conclusion**

This article provides a framework for identifying medical practices by introducing two key conditions: the cognitive requirement and the functional requirement. This dual approach gives us conditions to determine when an animal's health-promoting behaviour becomes medical. Moreover, our approach allows us to identify as medical animal practices that have been overlooked in the literature, such as care towards dying or disabled individuals, support during parturition, and bad medicine, while allowing us to discard as non-medical other animal practices like prophylaxis, highly stereotyped behaviours, and health-promoting activities with no fitness costs (such as nutrition). Lastly, our approach highlights the human-animal continuity while also stressing discontinuities in the animal kingdom. As we have argued, some animal practices show a mere difference of degree with human medical practices, and should be properly seen as medicine, while others entail a difference of kind, and deserve instead the nomenclature of therapeutic or prophylactic adaptations, but not medicine.

References

Abbott, J. (2014). Self-medication in insects: Current evidence and future perspectives. *Ecological Entomology*, *39*(3), 273–280. https://doi.org/10.1111/een.12110

Alfaro, J. W. L., Matthews, L., Boyette, A. H., Macfarlan, S. J., Phillips, K. A., Falótico, T., Ottoni, E., Verderane, M., Izar, P., Schulte, M., Melin, A., Fedigan, L., Janson, C., & Alfaro, M. E. (2012). Anointing variation across wild capuchin populations: A review of material preferences, bout frequency and anointing sociality in Cebus and Sapajus. *American Journal of Primatology*, *74*(4), 299–314. https://doi.org/10.1002/ajp.20971

Baracchi, D., Brown, M. J. F., & Chittka, L. (2015). Behavioural evidence for self-medication in bumblebees? *F1000Research*, *4*, 73. https://doi.org/10.12688/f1000research.6262.2

Bates, L. A., Byrne, R., Lee, P. C., Njiraini, N., Poole, J. H., Sayialel, K., Sayialel, S., & Moss, C. J. (2008). Do elephants show empathy? *Journal of Consciousness Studies*, *15*(10–11), 204–225.

Bizzell, F., & Pull, C. D. (2024). Ant queens cannibalise infected brood to contain disease spread and recycle nutrients. *Current Biology*, *34*(18), R848–R849. https://doi.org/10.1016/j.cub.2024.07.062

Bos, N., Sundström, L., Fuchs, S., & Freitak, D. (2015). Ants medicate to fight disease. *Evolution*, *69*(11), 2979–2984. https://doi.org/10.1111/evo.12752

Broadbent, A. (2019). *Philosophy of Medicine*. Oxford University Press.

Castella, G., Chapuisat, M., & Christe, P. (2008). Prophylaxis with resin in wood ants. *Animal Behaviour*, *75*(4), 1591–1596. https://doi.org/10.1016/j.anbehav.2007.10.014

Clark, I. R., Sandel, A. A., Reddy, R. B., & Langergraber, K. E. (2021). A preliminary analysis of wound care and other-regarding behavior in wild chimpanzees at Ngogo, Kibale National Park, Uganda. *Primates*, *62*(5), 697–702. https://doi.org/10.1007/s10329-021-00925-7

Clayton, D. H., & Wolfe, N. D. (1993). The adaptive significance of self-medication. *Trends in Ecology & Evolution*, *8*(2), 60–63. https://doi.org/10.1016/0169-5347(93)90160-Q

de Roode, J. C., & Huffman, M. A. (2024). Animal medication. *Current Biology*, *34*(17), R808–R812. https://doi.org/10.1016/j.cub.2024.07.034

de Roode, J. C., Lefèvre, T., & Hunter, M. D. (2013). Ecology. Self-medication in animals. *Science (New York, N.Y.)*, *340*(6129), 150–151. https://doi.org/10.1126/science.1235824

Danón, L. (2024). Normativity in Chimpanzees' Tool Behavior. *Topoi*. https://doi.org/10.1007/s11245-024-10137-5

Demuru, E., Ferrari, P. F., & Palagi, E. (2018). Is birth attendance a uniquely human feature? New evidence suggests that Bonobo females protect and support the parturient. *Evolution and Human Behavior*, *39*(5), 502–510. https://doi.org/10.1016/j.evolhumbehav.2018.05.003

Ding, W., Yang, L., & Xiao, W. (2013). Daytime birth and parturition assistant behavior in wild black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) Yunnan, China. *Behavioural Processes*, *94*, 5–8. https://doi.org/10.1016/j.beproc.2013.01.006

Douglas-Hamilton, I., Bhalla, S., Wittemyer, G., & Vollrath, F. (2006). Behavioural reactions of elephants towards a dying and deceased matriarch. *Applied Animal Behaviour Science*, *100*(1–2), 87–102. https://doi.org/10.1016/j.applanim.2006.04.014

Frank, E. T., Buffat, D., Liberti, J., Aibekova, L., Economo, E. P., & Keller, L. (2024). Wound-dependent leg amputations to combat infections in an ant society. *Current Biology*, *0*(0). https://doi.org/10.1016/j.cub.2024.06.021

Frank, E. T., Kesner, L., Liberti, J., Helleu, Q., LeBoeuf, A. C., Dascalu, A., Sponsler, D. B., Azuma, F., Economo, E. P., Waridel, P., Engel, P., Schmitt, T., & Keller, L. (2023). Targeted treatment of injured nestmates with antimicrobial compounds in an ant society. *Nature Communications*, *14*(1), Article 1. https://doi.org/10.1038/s41467-023-43885-w

Frank, E. T., Schmitt, T., Hovestadt, T., Mitesser, O., Stiegler, J., & Linsenmair, K. E. (2017). Saving the injured: Rescue behavior in the termite-hunting ant *Megaponera analis*. *Science Advances*, *3*(4), e1602187. https://doi.org/10.1126/sciadv.1602187

Frank, E. T., Wehrhahn, M., & Linsenmair, K. E. (2018). Wound treatment and selective help in a termite-hunting ant. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1872), 20172457. https://doi.org/10.1098/rspb.2017.2457

Freymann, E., Carvalho, S., Garbe, L. A., Ghazhelia, D. D., Hobaiter, C., Huffman, M. A., Muhumuza, G., Schulz, L., Sempebwa, D., Wald, F., Yikii, E. R., Zuberbühler, K., & Schultz, F. (2024). Pharmacological and behavioral investigation of putative self-medicative plants in Budongo chimpanzee diets. *PLOS ONE*, *19*(6), e0305219. https://doi.org/10.1371/journal.pone.0305219

Fuller, J. (2024). Demarcating scientific medicine. *Studies in History and Philosophy of Science*,106, 177-185.

Galef, B. G. (1990). A historical perspective on recent studies of social learning about foods by Norway rats. *Canadian Journal of Psychology*, *44*(3), 311–329. https://doi.org/10.1037/h0084261

Galef, B. G. (1993). Functions of social learning about food: A causal analysis of effects of diet novelty on preference transmission. *Animal Behaviour*, *46*(2), 257–265. https://doi.org/10.1006/anbe.1993.1187

Hart, B. L. (2011). Behavioural defences in animals against pathogens and parasites: Parallels with the pillars of medicine in humans. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1583), 3406–3417. https://doi.org/10.1098/rstb.2011.0092

Hemmes, R. B., Alvarado, A., & Hart, B. L. (2002). Use of California bay foliage by wood rats for possible fumigation of nest-borne ectoparasites. *Behavioral Ecology*, *13*(3), 381–385. https://doi.org/10.1093/beheco/13.3.381

Huffman, M. A. (1997). Current evidence for self-medication in primates: A multidisciplinary perspective. *American Journal of Physical Anthropology*, *104*(S25), 171–200. https://doi.org/10.1002/(SICI)1096-8644(1997)25+<171::AID-AJPA7>3.0.CO;2-7

Huffman, M. A. (2003). Animal self-medication and ethno-medicine: Exploration and exploitation of the medicinal properties of plants. *The Proceedings of the Nutrition Society*, *62*(2), 371–381. https://doi.org/10.1079/pns2003257

Huffman, M. A., Gotoh, S., Izutsu, D., Koshimizu, K., & Kalunde, M. S. (1993). Further Observations on the Use of the Medicinal Plant, Vernonia amygdalina (Del), by a Wild Chimpanzee, Its Possible Effect on Parasite Load, and Its Phytochemistry. *African Study Monographs*, *14*(4), 227–240. https://doi.org/10.14989/68112

Huffman, M. A., & Hirata, S. (2004). An experimental study of leaf swallowing in captive chimpanzees: Insights into the origin of a self-medicative behavior and the role of social learning. *Primates*, *45*(2), 113–118. https://doi.org/10.1007/s10329-003-0065-5

Huffman, M. A., Page, J. E., Sukhdeo, M. V. K., Gotoh, S., Kalunde, M. S., Chandrasiri, T., & Towers, G. H. N. (1996). Leaf-swallowing by chimpanzees: A behavioral adaptation for the control of strongyle nematode infections. *International Journal of Primatology*, *17*(4), 475–503. https://doi.org/10.1007/BF02735188

Huffman, M. A., & Seifu, M. (1989). Observations on the illness and consumption of a possibly medicinal plantVernonia amygdalina (Del.), by a wild chimpanzee in the Mahale Mountains National Park, Tanzania. *Primates*, *30*(1), 51–63. https://doi.org/10.1007/BF02381210

Jokura, K., Anttonen, T., Rodriguez-Santiago, M., & Arenas, O. M. (2024). Rapid physiological integration of fused ctenophores. *Current Biology*, *34*(19), R889–R890. https://doi.org/10.1016/j.cub.2024.07.084

Kacsoh, B. Z., Lynch, Z. R., Mortimer, N. T., & Schlenke, T. A. (2013). Fruit Flies Medicate Offspring After Seeing Parasites. *Science*, *339*(6122), 947–950. https://doi.org/10.1126/science.1229625

Kukla, Q. R. (2022). What Counts as a Disease, and Why Does It Matter? *The Journal of Philosophy of Disability*. https://doi.org/10.5840/jpd20226613

Laumer, I. B., Rahman, A., Rahmaeti, T., Azhari, U., Hermansyah, Atmoko, S. S. U., & Schuppli, C. (2024). Active self-treatment of a facial wound with a biologically active plant by a male Sumatran orangutan. *Scientific Reports*, *14*(1), 8932. https://doi.org/10.1038/s41598-024-58988-7

Lefèvre, T., Oliver, L., Hunter, M. D., & de Roode, J. C. (2010). Evidence for trans-generational medication in nature. *Ecology Letters*, *13*(12), 1485–1493. https://doi.org/10.1111/j.1461-0248.2010.01537.x

Lozano, G. A. (1998). Parasitic Stress and Self-Medication in Wild Animals. In A. P. Møller, M. Milinski, & P. J. B. Slater (Eds.), *Advances in the Study of Behavior* (Vol. 27, pp. 291–317). Academic Press. https://doi.org/10.1016/S0065-3454(08)60367-8

Mascaro, A., Southern, L. M., Deschner, T., & Pika, S. (2022). Application of insects to wounds of self and others by chimpanzees in the wild. *Current Biology*, *32*(3), R112–R113. https://doi.org/10.1016/j.cub.2021.12.045

Mason, J. R., & Reidinger, R. F. (1982). Observational Learning of Food Aversions in Red-Winged Blackbirds (Agelaius phoeniceus). *The Auk*, *99*(3), 548–554.

Melis, G., & Monsó, S. (2024). Are Humans the Only Rational Animals? *The Philosophical Quarterly*, *74*(3), 844–864. https://doi.org/10.1093/pq/pqad090

Moore, B. D., Foley, W. J., Forbey, J. S., & Degabriel, J. L. (2013). Self-medication: A learning process? *Science*, *340*(6136), 1041. https://doi.org/10.1126/science.340.6136.1041-b

Nakajima, S. (2018). Clay eating attenuates lithium-based taste aversion learning in rats: A remedial effect of kaolin on nausea. *Physiology & Behavior*, *188*, 199–204. https://doi.org/10.1016/j.physbeh.2018.02.020

Neco, L. C., Abelson, E. S., Brown, A., Natterson-Horowitz, B., & Blumstein, D. T. (2019). The evolution of self-medication behaviour in mammals. *Biological Journal of the Linnean Society*, *128*(2), 373–378. https://doi.org/10.1093/biolinnean/blz117

Ohashi, G., & Matsuzawa, T. (2011). Deactivation of snares by wild chimpanzees. *Primates; Journal of Primatology*, *52*(1), 1–5. https://doi.org/10.1007/s10329-010-0212-8

Pan, W., Gu, T., Pan, Y., Feng, C., Long, Y., Zhao, Y., Meng, H., Liang, Z., & Yao, M. (2014). Birth intervention and non-maternal infant-handling during parturition in a nonhuman primate. *Primates; Journal of Primatology*, *55*(4), 483–488. https://doi.org/10.1007/s10329-014-0427-1

Park, K. J., Sohn, H., An, Y. R., Moon, D. Y., Choi, S. G., & An, D. H. (2012). An unusual case of care-giving behavior in wild long-beaked common dolphins (Delphinus capensis) in the East Sea. *Marine Mammal Science*, *29*(4), E508–E514. https://doi.org/10.1111/mms.12012

Peckre, L. R., Defolie, C., Kappeler, P. M., & Fichtel, C. (2018). Potential self-medication using millipede secretions in red-fronted lemurs: Combining anointment and ingestion for a joint action against gastrointestinal parasites? *Primates*, *59*(5), 483–494. https://doi.org/10.1007/s10329-018-0674-7

Rozin, P. (1976). The Selection of Foods by Rats, Humans, and Other Animals. In J. S. Rosenblatt, R. A. Hinde, E. Shaw, & C. Beer (Eds.), *Advances in the Study of Behavior* (Vol. 6, pp. 21–76). Academic Press. https://doi.org/10.1016/S0065-3454(08)60081-9

Sato, Y., Hirata, S., & Kano, F. (2019). Spontaneous attention and psycho-physiological responses to others' injury in chimpanzees. *Animal Cognition*, *22*(5), 807–823. https://doi.org/10.1007/s10071-019-01276-z

Simone, M., Evans, J. D., & Spivak, M. (2009). Resin collection and social immunity in honey bees. *Evolution; International Journal of Organic Evolution*, *63*(11), 3016–3022. https://doi.org/10.1111/j.1558-5646.2009.00772.x

Singer, M. S., Mace, K. C., & Bernays, E. A. (2009). Self-Medication as Adaptive Plasticity: Increased Ingestion of Plant Toxins by Parasitized Caterpillars. *PLOS ONE*, *4*(3), e4796. https://doi.org/10.1371/journal.pone.0004796

Solomon, M. (2015). *Making Medical Knowledge*. Oxford University Press.

Suárez-Rodríguez, M., López-Rull, I., & Macías Garcia, C. (2013). Incorporation of cigarette butts into nests reduces nest ectoparasite load in urban birds: New ingredients for an old recipe? *Biology Letters*, *9*(1), 20120931. https://doi.org/10.1098/rsbl.2012.0931

Sueda, K. L. C., Hart, B. L., & Cliff, K. D. (2008). Characterisation of plant eating in dogs. *Applied Animal Behaviour Science*, *111*(1), 120–132. https://doi.org/10.1016/j.applanim.2007.05.018

Sun, Q., & Zhou, X. (2013). Corpse Management in Social Insects. *International Journal of Biological Sciences*, *9*(3), 313–321. https://doi.org/10.7150/ijbs.5781

Villalba, J. J., Provenza, F. D., & Shaw, R. (2006). Sheep self-medicate when challenged with illness-inducing foods. *Animal Behaviour*, *71*(5), 1131–1139. https://doi.org/10.1016/j.anbehav.2005.09.012

Vitazkova, S. K., Long, E., Paul, A., & Glendinning, J. I. (2001). Mice suppress malaria infection by sampling a 'bitter' chemotherapy agent. *Animal Behaviour*, *61*(5), 887–894. https://doi.org/10.1006/anbe.2000.1677

Wrangham, R. W., & Nishida, T. (1983). Aspilia spp. Leaves: A puzzle in the feeding behavior of wild chimpanzees. *Primates*, *24*(2), 276–282. https://doi.org/10.1007/BF02381090

Yinda, L. E. D. O., Onanga, R., Obiang, C. S., Begouabe, H., Akomo-Okoue, E. F., Obame-Nkoghe, J., Mitola, R., Ondo, J.-P., Atome, G.-R. N., Engonga, L.-C. O., Ibrahim, Setchell, J. M., & Godreuil, S. (2024). Antibacterial and antioxidant activities of plants consumed by western lowland gorilla (Gorilla gorilla gorilla) in Gabon. *PLOS ONE*, *19*(9), e0306957. https://doi.org/10.1371/journal.pone.0306957