Self-Medication in Chimpanzees (Pan Troglodytes) or Why Ethnobotanists should include Great Apes into their Studies

CAS in Ethnobotany and Ethnomedicine 2018, University of Zurich

Myriam Jager-Honegger

Index

Picture on title page was taken by the author at the Zoological Garden, Basel on July 26th, 2018.

1 Introduction

Life without plants is unheard of for chimpanzees as well as for humans. A minority of plants is suitable for food, some are poisonous and some have additional medical benefits. The knowledge of herbal remedies has been transferred through generations of chimpanzees or humans as part of folk medicine. Due to our phylogenetic closeness, humans and chimpanzees select the same plants to treat the same symptoms. These implications are very interesting when we consider the evolution of medicinal habits from the ancestors of the great apes to early hominids and modern humans (Huffman 1997, McGrew 2004, Padhi 2013).

In this review, the self-medicative behaviour of chimpanzees (*Pan troglodytes*) will be discussed as an example of why ethnobotanist should keep a wide horizon and include apes in their studies.

A short overview of the history of chimpanzees and humans, a concept of culture and tradition as used in this paper and an introduction into Theory of Mind are given in the introductory section as a base to the subsequent discussion and conclusion.

1.1 Pan Troglodytes and Homo Sapiens

Chimpanzees and humans share a common ancestry separating more than 4.5 million years ago. Our last common ancestor must have been an arboreal frugivore/omnivore. From there, ways have separated into two different directions: One along the road of development of a partially arboreal, facultative bipedal woodland omnivore called *Ardipithecus* and further to a striding terrestrial biped pan-African wide-niched *Australopithecus* to the enlarged-brained, technology-reliant *Homo sapiens*. The genus *Pan* developed into frugivorous, mostly ground living knuckle-walking chimpanzees (*Pan troglodytes)* and bonobos (*Pan paniscus*) (White 2009, Owen Lovejoy 2009, Mittermeier 2013).

What humans and chimpanzees still have in common is a skill-intensive feeding niche, coupled with a large brain and a significant amount of learning during the adult period (Kaplan 2000).

Chimpanzees occupy the largest geographical area of all great apes with habitats in diverse climatic zones, from rainforest to savannah, from sea-level to a maximum altitude of almost 2800 m above sea level. Chimpanzees are distributed from southern Senegal between 13°N and 7°S to western Uganda and western Tanzania (IUCN and Red List, McGrew 2004).

The genus *Pan* is divided into four subspecies and separated by lack of forest or by large inland waters:

- *Pan troglodytes verus*: the Western Chimpanzee; has one range of distribution from Senegal to Ghana and a second in western Nigeria.
- *Pan troglodytes ellioti*: has the smallest range of distribution and lives only in Nigeria and Cameroon north of the Sanaga River
- *Pan troglodytes troglodytes*: the Central Chimpanzee; inhabits the area in Cameroon south of the Sanaga River to the Congo and Ubangi River in the Democratic Republic of Congo
- *Pan troglodytes schweinfurthii*: the Eastern Chimpanzee; their range of distribution starts with the Congo and Ubangi River in the Democratic Republic of Congo, crosses Burundi and Rwanda and reaches in the East western Uganda and western Tanzania (IUCN and Red List, McGrew 2004).

1.2 Culture and Tradition

There are two processes that can generate evolutionary change: the transmission of behavioural change from one generation down to another happens either genetically or through social learning (Whiten 1999). In the first case we are talking about biological evolution, in the second about cultural evolution.

A cultural behaviour is one that is transmitted repeatedly through social or observational learning to become a population-level characteristic or a tradition. A tradition is a group-typical behaviour by members of a community that relies on transmitted information. It is a collective body of knowledge and action that shows continuity over time within a group and the transmission goes from older to younger individuals to build continuity over generations. Traditions are the key to culture: tradition is both a necessary and a sufficient condition (Whiten 1999, McGrew 2004).

Another requirement for tradition and subsequently for culture is social learning. Much of the behavioural repertoire is adaptively shaped by learning from others and this effect spans multiple consecutive generations. Imitation is one of the less cognitively complex processes in social learning but it requires the transformation of visually perceived action by an observed individual into action by the observer. Imitation permits the highest quality of pattern-transmission and the spread of cultural transition. Chimpanzees also show a functional bias of learning from the best, copying and even overriding the best (Whiten 2018, Hoffman 2010, Rendell 2011).

Chimpanzees have a remarkable ability to invent new customs and technologies and to pass these on to the following generations (De Waal 1999). Chimpanzees depend on material culture as much as humans do:

- Chimpanzees build at least one shelter a day where they sleep at night and rest during the day.
- They fish with sticks for termites or ants or crack nuts with hammers and in some places with anvils
- Chimpanzees use objects as weapons for hunting or fighting.
- They use defined plants in self-maintenance such as in self-medication
- They use leaves as napkins or sponges or to sit on instead of on the bare ground.

The use of such tool kits make chimpanzees to generalists in material culture. There is – apart from humans – no other species that uses elementary technology in so many aspects of life (McGrew 2004).

1.3 Theory of Mind and Empathy

Premack and Woodruff defined Theory of Mind in 1978 as the ability to impute mental states to one self and others (Premack 1978, Schlinger, 2009). In a series of experiments with primates, they concluded that "not only man but also apes had theories of mind" (Premack 1978). What chimpanzees failed is the so called "false beliefs test". But, as evidence suggests, human children under the age of four, signing deaf children from hearing families and children diagnosed with autism do have their difficulties with this part of Theory of Mind (Call 2008, Schlinger 2009).
There is one Chimpanzee group in Mahale, Tanzania, that engages in social scratching: during the daily grooming sessions the groomer scratches, almost in slow motion, the groomee's back, trunk or limbs. Social scratching shows signs of empathy: the scratcher must recall that being scratched felt good and so by second order intentionality (= I know that you know) can put him or herself in the groomee's place (McGrew 2004).

Based on the above introduced theories, the questions of why great apes should be included into ethnobotanical studies will be illustrated by the example of chimpanzee self-medication.

2 Materials and Methods

To review the topic, a backward snowballing system was used, starting with an unpublished research plan (Weckerle 2012) and going backwards with each source found.
Personal inputs on the topic and more insights on chimpanzees were received from Adrian Baumeyer, Zoological Garden Basel, Switzerland, and integrated in the searches and sources.

To find more recent publications, online searches were performed using the key words "chimpanzee" or "Pan troglodytes" in Google Scholar plus the most appropriate term for the given topic.
All sources were accessible either as a paper copy at the Zentralbibliothek Zürich or made available as a PDF-file by the University of Zurich.

3 Findings

3.1 Food as Medicine and Medicine as Food

Zoopharmacognosy, the study of self-medication in animals, is relatively young as a science but humans have traditionally looked at animals as a source of medicinal knowledge. The basic premise is that animals use plant secondary compounds or other non nutritional substances to medicate themselves (Huffman 1997). The main trigger for (self-) medication in all species is the need to feel well, to maintain or restore a physiological homeostasis (Huffman 2016).
Zoopharmacognosy is best studied in African great apes as they show the clearest evidence for self-medication: certain plant parts are ingested directly for their significant medicinal value (Huffman 1997, Huffman 2003, Huffman 2016). The two most famous examples of self-medicative behaviours in chimpanzees, "Whole Leaf-Swallowing" and "Bitter Pith-Chewing" are discussed below. Both of them occur in the context of intestinal parasites, either to reduce the burden of intestinal nematodes and/or tapeworms or to provide relief from related gastrointestinal pain. Parasites can cause a variety of diseases with negative impact on overall behaviour and reproductive fitness, so there seemed to be a great need to counteract such a great pressure. The mutual effects on host and host response are the effect of a long evolutionary process (Huffman 1997, Huffman 2001).
Plants can be ingested for many purposes, some examples are to reduce the risk of infections by parasites or bacteria present in the digestive tract of prey, to season or flavour food or to improve the texture. This is usually done by combining fragrant leaves with meat. These plants usually contain low-content secondary bioactive compounds that can contribute prophylactically to health maintenance, when eaten regularly (Krief 2015).
In the 1980s, the concept of "food as medicine and medicine as food" was introduced, meaning that compounds found in the ordinary diet may have important positive effects on health and could prevent risks of infections and other illnesses (Krief 2006, Krief 2015, Huffman 1997).

The difference of food and medicine is often difficult to detect and there is much overlap both in humans and in chimpanzees. But in modern western societies, much of the non-nutritional components that were once part of our daily diet have been replaced by herbal medicines or most recently with so-called super-foods (Huffman 2015).

As time passed, the consumption of specific bioactive plants in association with certain stimuli such as malaise or disease created a growing difference between food and medicine (Masi 2011). In order to react adequately to those stimuli, a high level of cognitive functions is required. An individual has to identify the symptoms, distinguish between the use of a plant as a therapeutic agent or as a forage plant, recognise a positive change in its health and even provide some evidence for the activity of the chosen plant (Huffman 2017). Aspects of self-medication in chimpanzees are acquired by social learning and the knowledge is transmitted from generation to generation and maintained within the group as part of their culture (Huffman 2017).

Anti-parasite behaviour is in most species the primary reason for self-medication and is as an adaptive process the result of a long evolutionary process (Hardy 2013, Huffman 2004, Villalba 2014).

Nodular worm infections are associated with significantly more Bitter Pith-Chewing and Whole Leaf-Swallowing than other parasite infections and *Oesophagostomum stephanostomum* being the most dangerous to chimpanzees. Repeated and chronic infections may lead to complications including secondary bacterial infections, prolonged diarrhoea, severe abdominal pain, weight loss, weakness, reduced reproductive fitness and increased mortality (Huffman 2013).

Inter-individual social networks and social tolerance play important roles in the transmission of self-medicative behaviour (Krief 2015).

Regional differences in plant selection might rather be related to the traditional use of a certain plant in a given group than to species availability e.g. *Acanthus pubescens* flowers are eaten at Budongo, Uganda, but at Kanyawara, Uganda, the stems are eaten (Krief 2015).

Secondary compounds and inorganic materials are synthesized by plants as a frontline defence against herbivores, pests, and diseases. They are toxic when consumed or deter consumption by reducing the palatability or digestibility. And yet there are a number of plants with such secondary compounds found in the diet of great apes (Huffman 1997). One example is given in Table 3.1-1

Table 3.1-1 Plants with toxic secondary compounds in chimpanzee diet (Huffman 1997, Kariuki 2018)

Plant	compound(s)	Diet	Comments
Phytolacca dodecandra L'Herit (Phytolaccacea)	concentrated source of at least 4 triterpenoid saponins • lemmatoxin • lemmatoxin-c • oleanoglycotoxin-A • phytolacca-dodecandra glycoside	Berries frequently ingested at Kanyawara	Used by humans in Kenya in the control of snails transmitting schistosomiasis and as a molluscicide in Ethiopia

Schistosomiasis is a devastating tropical disease and ranked second after Malaria in terms of number of people at risk of infection and causes death of around 200'000 people in sub-saharan Africa. It is caused by *Schistosoma trematodes* with freshwater snails as their intermediate hosts. Contagion takes place when people come in contact with infested water (Kariuki 2018). Berries of *Phytolacca* species are also used in western herbal medicine as emetics and cathartics (Cock 2015), probably due to their saponine content.

3.2 Whole Leaf Swallowing

Whole Leaf-Swallowing is unlikely to provide any nutritional value, but is a behaviour widely practiced, not only by all four sub-species of chimpanzee, but also by bonobos and low-land gorillas across Africa to expel parasites (Huffman 2010, Huffman 2017).

Whole Leaf-Swallowing is one of the best documented self-medicative behaviours in animals overall: there are documentations from at least 16 sites with 25 chimpanzee communities, spanning the entire geographical distribution (Huffman 2015).

Whole Leaf-Swallowing is a cultural practice for the adaptive control of intestinal parasites: infants see their mothers do it from an early age on and soon begin to mimic this behaviour.

In an experimental setting in an Italian zoo, branches of *Helianthus tuberosus* were given to two separated groups of chimpanzees. In every observational session, a single branch was given to an individual. The reactions of the individuals to the yet unknown plant was observed. Each individual showed a self-motivated interest in exploring the plant an learnt individually how to fold and swallow the leaves. Those who performed Whole Leaf-swallowing never observed another individual swallow leaves, and not all individuals were interested in the plants. Those chimpanzees who observed others swallow the leaves seemed to have been influenced by the variant they have seen (folding the whole leave several times versus tearing leave the in parts before folding). This option-biased social learning created homogeneity within the group but a difference between the groups that was significantly greater than expected in the absence of social-learning (Huffman 2010).

The motivation of Whole Leaf-Swallowing is not based on understanding the anti-parasitic action but is acquired as another one of the mothers' groups typical behaviours. The therapeutic value of Whole Leaf-Swallowing is likely to be realized later in life as a consequence of associative learning about the predictable curative effects (or symptomatic relieve) if appropriately performed (Huffman 2010).

There is a pivotal difference between leaf eating and Whole Leaf-Swallowing: in leaf eating, several leaves are consumed at the same time and chewed. In Whole Leaf-Swallowing, each leaf is treated singularly. Slowly and deliberately, each leaf at the time is carefully folded from the distal half between tongue and palate, slowly pulled into the mouth and swallowed whole, where it passes the gastrointestinal tract undigested. The number of leaves swallowed in one bout varies between 1 and 100. Defecation occurs within six hours (Huffman 2001, Huffman 2003, Huffman 2010).

The mechanism of action in nematode infection is mechanical: the purgative expulsion of adult worms disrupts their lifecycles (Krief 2004, McLennan 2012, Huffman 2015). Faecal sampling studies showed that that the expelled parasites always were loose in the dung and never found in between the folds or attached to the leaf surface. The dung consistency was usually not very firm, an indication of gastrointestinal upset (McLennan 2012).

There is a strong statistical connection between Whole Leaf-Swallowing and the expulsion of nodular worms. Repeated swallowing of leafs over consecutive days or weeks and the resulting repeated flushing of the gastrointestinal tract has a significant impact on the overall worm burden (Huffman 2001, McLennan 2012).

In tapeworm infections, it may have a pain relieving effect (Huffman 2001). And therefore it is suggested that the proximate stimulus is not the parasitic infection per se but the relief from the concomitant abdominal discomfort or pain due to the purging effect without inducing diarrhoea (McLennan 2012).

Over 30 plant species are used in Whole Leaf-Swallowing. The life forms of the plants vary, from herbs to vines to shrubs to bushes to trees. But their leaves share one common property: they are bristle, rough-surfaced, covered in trichomes or stiff hairs and are difficult to digest (Huffman 2001, Huffman 2003, Huffman 2017). In Table 3.2-2 are examples of plants listed that are chosen by chimpanzees for Whole Leaf-Swallowing.

Table 3.2-2Whole Leaf Swallowing

Plant	Site	Source
Acalypha sp.	Bulindi, Uganda	McLennan 2012
Aneilema aequinoctiale	Mahale, Tanzania	Huffman 2001
Aneilema nyasense	Bulindi, Uganda	McLennan 2012, McLennan 2017
Aspilia sp. eg. *mosambicensis, pluriseta, rudis*	Bulindi, Uganda Gombe and Mahale, Tanzania	Huffman 2003, Huffman 2006, McGrew 2004
Desmodium velutinum	Bulindi, Uganda	McLennan 2012, McLennan 2017
Erythroccoca trichogyne	Bulindi, Uganda	McLennan 2012
Ficus asperifolia	Kibale, Uganda	Krief 2006
Ficus exasperata	Kibale, Uganda	Krief 2006
Lantana camara	Bulindi, Uganda	McLennan 2012, McLennan 2017
Trema orientalis	Mahale, Tanzania	Huffman 2001

3.3 Bitter Pith-Chewing

Bitter Pith-Chewing aids in the control of intestinal nematode infections and concomitant gastrointestinal pain by pharmacological action. There is substantial evidence from ethnobotanical, parasitological and pharmacological observations that support the hypothesis that Bitter Pith-Chewing is a therapeutic form of chimpanzee self-medication (Huffman 2015). The plants used by chimpanzees to chew the bitter pith are listed in Table 3.3-3.
A chimpanzee removes with utmost care the outer bark and the leaves of a young shoot. Then the individual chews on the exposed pith on a length of about 5-120 cm to extract the bitter juice and the residual amounts of fibre. This whole procedure takes about 1 to 8 minutes (Huffman 2001).
Recovery time is around 20 to 24 hours, which is comparable to that of the Tongwe people who use cold concoctions as a treatment against parasites, diarrhoea, and stomach upsets (Huffman 1997).
Adult chimpanzees show no interest in others chewing on “bitter pith”. But infants of ill mothers are known to closely watch their behaviour and to immediately try to perform it themselves or to taste small amounts of the pith discarded by their mothers (Huffman 2001, Huffman 2015).

Table 3.3-3 Plants used for bitter pith chewing

Plant	**Site**	**Source**
Vernonia amygdalina	Bulindi, Uganda Mahale, Tanzania	McGrew 2004 Huffman 2016
Vernonia colorata	Gombe, Tanzania	Huffman 2001
Vernonia hochstetteri	Kahuzi-Biega, Democratic Republic of Congo	Huffman 2001
Vernonia kirungae	Kahuzi-Biega, Democratic Republic of Congo	Huffman 2001
Eremospath macrocarpa	Tai, Ivory Coast	Huffman 2003
Paliosota hirsuta	Tai, Ivory Coast	Huffman 2003

For traditional healers in Tanzania, there is no difference whether in medicinal properties nor in folk taxonomic between *Vernonia amygdalina* and *Vernonia colorata*. Both very closely related species are classified as one taxon of "bitter-leaf" due to the extremely bitter taste (Huffman 2001, Berlin 1973). *Vernonia* sp. is widely used throughout Africa to treat a multiplicity of diseases. Leaf extracts showed in vitro anti-plasmodial activity. They also show bioactivity against a number of protozoan and helminth parasites (Massaba 2000, Krief 2004).
The pharmacologically active secondary compounds are steroid glycosides (vernonioside A_1-A_4, B_1-B_3 and two freely occurring aglycons of these glycosides: vernonid A_1, B_1) and sesquiterpene lactones (vernadoline, vernolide hydroxyvernolide, vernodalol). Vernadoline is a highly toxic substance that is abundant in the leaves and the bark of *Vernonia* sp. but only present in insignificant amounts in the pith, where high concentrations of the steroid glycosides are found (Huffman 1997). This might explain why chimpanzees make such an effort to remove the leaves and the bark and only chew on the exposed pith. Despite the very bitter taste for which *V. amygdalina* would not be consumed for feeding purposes, it is still ingested because of the chimpanzees clear knowledge of its therapeutic value. This is also an example of an intentional action similar to building a tool for future use

4 Discussion and Conclusion

4.1 Ethnobotanical Consistency of Chimpanzee and Human Plant Use

There is a great overlap in the use of particular medicinal plants used by African great apes and contemporary humans. It is not only the widespread cultural practice of humans to observe the behaviour of sick animals to find new sources of healing but also the physiological proximity that makes us prone to similar diseases (Huffman 2015). Since the beginnings of chimpanzee observations at Kibale, Uganda, 117 food plant species have been identified. Research has shown that approximately one quarter of them is used in traditional medicine in different countries across Africa (Krief 2015). One third of the plant parts ingested by chimpanzees correspond to the according plant parts used in ethnomedicine (Huffman 2015).

Medicinal plants used by humans and chimpanzees are summarised in Table 4.1-4

There are only two extensively studied examples of self-medication in chimpanzee. But it is not known, whether unusual or bioactive food is consumed for a medical reason. Further studies might reveal the purpose behind the consumption of one or the other plant.

Table 4.1-4 plants used by humans and chimpanzee

Plant	Used by	Used for/Indication	Where	Plant part used	Source
Chaetacme aristata	Chimpanzee	Eaten with wasp comb, UBF	Kibale, Uganda	Leaves, Bark	Krief 2005 Krief 2006, Krief 2015, Masi 2012
	Human	Anti-tuberculosis, haemorrhoids	Republic of Central Africa	Leaves Bark	
Clerodenrum buchholzii	Chimpanzee	UBF	Kibale, Uganda	Leaves	Krief 2005
	Human	Carbuncle	Democratic Republic of Congo	Leaves	
Crassocephalum bojeri	Chimpanzee	UBF	Kibale, Uganda	Leaves	Krief 2005
	Human	Fever, malaria, de-toxicant, rhinitis, influenza	Kenya Tanzania	Leaves	
Diospyros abyssinica	Chimpanzee	Eaten with red colobus or wasp comb, UBF	Kibale, Uganda	Bark leaves	Krief 2015 Krief 2006 Masi 2012
	Human	Wound, foot fungal infection	Not mentioned	Leaves/seeds	
Ficus asperifolia	Chimpanzee	**Whole Leaf-Swallowing**, UBF	Kibale, Uganda	Leaves	Krief 2006 Krief 2005
	Human	Fever, gonorrhoea, haemorrhoids, sterility in women	Democratic Republic of Congo	Leaves	
Ficus exasperata	Chimpanzee	UBF, **Whole Leaf-Swallowing**	Kibale, Uganda	Bark, Leaves	Krief 2006, Krief 2005
	Human	**Anthelmintic**, plaster on ringworm, furred tongue, tonsillar inflammation, venereal illnesses, vaginal carbuncle, dermatosis high blood pressure, anti-ulcer, **stomach disorder**, herpes, gingivitis, mouth affection, **stomach aches**, pruritus and leprosy ulcer, rheumatism, oedema, leprous ulcer, application on abscess, tinea, ophthalmic condition, analgesic	Tanzania Sierra Leone Nigeria French Guinea Democratic Republic of Congo Central African Republic	Leaves	

Plant	Used by	Used for/Indication	Where	Plant part used	Source
Ficus natalensis	Chimpanzee	UBF	Kibale, Uganda	Bark, flowers, fruits	Krief 2005, Krief 2006, Masi 2012
	Human	Infectious venereal disease galactagogue, influenza	South and East Africa Tanganyika	Entire plant Bark	
Ficus sur	Chimpanzee	Eaten with red colobus or wasp comb, UBF	Kibale, Uganda	Not mentioned	Krief 2005 Krief 2006 Krief 2015
	Human	Abscess, leprous ulcer Reproductive stimulation, **laxative**, abortifacient, aphrodisiac, pain	Democratic Republic of Congo West Africa Ivory coast	Fruit Unripe fruit	
Ficus urceolaris	Chimpanzee	Eaten with wasp comb	Kibale, Uganda	Leaves, unripe fruits	Krief 2015 Masi 2012
	Human	Fever, sterility	Not mentioned	Leaves	
Hoslundia opposita	Chimpanzee	UBF	Kibale, Uganda	Fruit	Krief 2005
	Human	Eye disease, oedema, itching, skin disease, rheumatism, liver disease, icterus	Ivory Coast	Fruit	
Laportea aestuans	Chimpanzee	UBF	Kibale, Uganda	flowers	Krief 2005
	Human	Laryngitis	Democratic Republic of Congo	Flowers	
Monodora myristica	Chimpanzee	UBF	Kibale, Uganda	Fruits, seeds, leaves	Krief 2005, Krief 2006 Masi 2012,
	Human	**Anthelmintic**, **gastric disease**, wounds, **anti-emetic**, tonic, headaches, rhino-pharyngitis	Central African Republic	seeds	
Myrianthus arboreus	Chimpanzee	UBF	Kibale, Uganda	Stems, seeds	Krief 2005 Masi 2012
	Humans	**Dysentery**, urethral discharge helps to give birth, dysmenorrhea, hernia, analgesia (teeth), bronchitis, throat affections, **emetic** and **purgative**	West Africa Democratic Republic of Congo	Leaves Stems Fruits	
Neoboutania macrocalyx	Chimpanzee	UBF	Not mentioned	Dead wood, bark root, leaves	Masi 2012
	Human	**Stomach ache**, malaria, fever, **dysentery**, abortion, psychoses, witchcraft	Not mentioned	Bark/leaf	
Olea welwitschii	Chimpanzee	UBF	Kibale, Uganda	Wood/bark	Krief 2005, Krief 2006, Masi 2012
	Human	Gonorrhoea, cough	Not mentioned	Leaves, bark	
Pennisetum purpureum	Chimpanzee	UBF	Kibale, Uganda	Stems	Krief 2005
	Human	**Internal parasitism, amoebiasis, anthelmintic, vermifuge**	Guinea	Leaves and stems	
Phytolacca dodecandra	Chimpanzee	UBF	Kibale, Uganda	Fruits	Krief 2005, Kariuki 2018 Masi 2012
	Human	Bilharziosis, schistosomiasis (molluscicide)	Ethiopia	Fruits	
Rubia cordifolia	Chimpanzee	UBF	Kibale, Uganda	Leaves	Krief 2005,

Plant	Used by	Used for/Indication	Where	Plant part used	Source
	Human	**Diarrhoea**, pleurisy, inflammatory conditions in chest, pain, wounds or cuts, **emetic**, sterility in women	Kenya South Africa Tanzania Congo	Leaves and roots	Masi 2012
Securinega virosa	Chimpanzee	UBF	Kibale, Uganda	Fruits	Krief 2005
	Human	Snake bite	Kenya	Fruits	
Solanecio manii	Chimpanzee	Not mentioned	Tanzania	Pith	Krief 2005, Masi 2012
	Human	Wounds, **purgative**, oedema, skin lesion, abscess, **dysentery**, cardiac pain, baby delivery, urinary disease, malaria, fever, asthma	Not mentioned	Leaves, stem	
Teclea nobilis	Chimpanzee	Eaten with red colobus	Kibale, Uganda	Leaves	Krief 2015, Masi 2012
	Human	Malaria, anaemia, rachitis	Not mentioned	Leaves, bark	
Toddalia asiatica	Chimpanzee	UBF	Kibale, Uganda	Fruits	Krief 2005
	Human	Cough	Kenya	Fruits	
Trichillia rubescens or dregeana	Chimpanzee	UBF	Kibale, Uganda	Leaves, seeds, flowers	Krief 2004, Krief 2005, Masi 2012
	Human	Rectal ulcer, **dysentery, purgative**, soporific, bruises, gonorrhoea, itching, rheumatism	Tanzania (Ronga) Southern Africa (Zulu) Democratic Republic of Congo	Bark, leaves seeds	
Vernonia amygdalina	Chimpanzee	**Bitter pith chewing**	Tropical, sub-saharan Africa	Young shoot	Huffman 2003, Huffman 2016, Huffman 2001, Huffman 2015 McGrew 2004
	Human	Schistosomiasis, **diarrhoea**, **amoebic dysentery and other parasites**, **constipation,** ringworm, **enteritis,** malaria, **trematode infection, stomach upset and aches**	West to East Africa, Democratic Republic of Congo Zimbabwe, Mozambique, Nigeria, South Africa, Tanzania, Ethiopia, Angola, Guinea	Stem, root bark, leaves, fruit, sap, seed, bark	

***** Chimpanzee: self-medication of wild living animals
UBF: unusual and bioactive food

Malaria in apes is known to be subclinical or mildly pathogenic, but when coupled with other diseases, malaria can become detrimental (Krief 2006). To observe whether or not a chimpanzee is infected with malaria is difficult to impossible and could lead to the assumption that a plant is a rarely consumed food item when in fact it is consumed as a treatment for mild yet bothering symptoms of malaria. In Table 4.1-5, unusual and bio-active food for chimpanzees and plants used by humans for fever and malaria are summarised.

Table 4.1-5plants used for same indications (among others fever and malaria) in chimpanzee and humans

Plant	Used by*	where	Plant part used	Source
Crassocephalum bojeri	Chimpanzee	Kibale, Uganda	Leaves	Krief 2005
	Human	Kenya Tanzania	Leaves	
Ficus exasperata	Chimpanzee	Kibale, Uganda	Bark	Krief 2006, Krief 2005
	Human	Tanzania Sierra Leone Nigeria French Guinea Democratic Republic of Congo Central African Republic	Leaves	
Neoboutania macrocalyx	Chimpanzee	Not mentioned	Dead wood, bark root, leaves	Masi 2012
	Human	Not mentioned	Bark/leaf	
Vernonia amygdalina	Chimpanzee	Tropical, sub-saharan Africa	Young shoot	Huffman 2003, Huffman 2016, Huffman 2001, Huffman 2015 McGrew 2004
	Human	Democratic Republic of Congo, Zimbabwe, Mozambique, Nigeria, South Africa, Tanzania, Ethiopia, Angola, Guinea	Stem, root bark, leaves, fruit, sap, seed, bark	

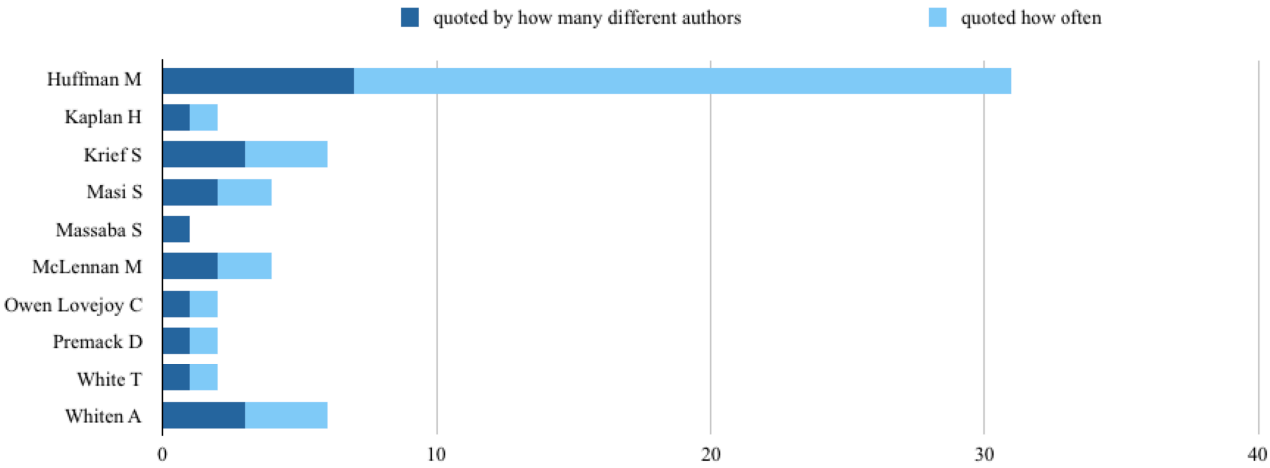
***** Chimpanzee: self-medication of wild living animals

4.2 Bias and Weakness of This Review

There is a bias of observation site as well as a bias of habituation in this review. The main observation sites are at the very east – Bossou, Guinea and Taï Forest, Ivory Coast – and at the very west – Budongo and Kibale, Uganda as well as Gombe and Mahale, Tanzania – of the chimpanzees distribution range (Whiten 1999). Lack of data from the Congo basin is in my view due to underreporting and not due to lack of chimpanzee culture. Before 2004, when the main observations in the literature used were done, only seven of the populations were classed as habituated, i.e. tolerant of human observers at a close range (McGrew 2004).

There is a bias of overuse of the work of M.A. Huffman in this review. Around 1/6 of the literature chosen is written by M.A. Huffman and in another 4 papers does he appear as a co-author. He is also by far the most quoted author in the sum of all quotes in my literature as can be seen in Figure 4-1. The authors not mentioned in the figure have not been quoted in the literature used in this review. There are several more articles written by M.A. Huffman that influenced the work of the authors quoted in this review but are not included into my selection of literature.

Figure 4-1 Overrepresentation of M.A. Huffman's work



In contrast to usual ethnobotanical studies, it is not possible to talk to chimpanzees. Therefore knowledge about plant use depends on the observer and the time period of the observations. It is for example not possible to ask what they do when they run out of their preferred plant and what alternatives they use when the preferred plant is not in season.

On the other hand, as chimpanzees do not know shame (personal communication A. Baumeyer) they do not conceal information because it seems impure, shameful, negligible ore simply not noteworthy.

The information that are received from chimpanzee observations are observer dependent, but this bias can be cancelled out with enough observations by enough different observers at different times during seasons and daytimes over the years.

4.3 Conclusion

One major question still remains unanswered: how do chimpanzees choose their medicinal plants? Is it based on trial and error? Is it convergence on a yet unknown catalogue of criteria? Chimpanzees, like other primates react to unknown food with neophobia (Masi 2012). Chimpanzee culture does not only include material culture and skills that are learned by a young individual in the context of its mothers' social group. It is not yet known, how such specific plant choices are made. Even though the organoleptic characteristics of a plant are culturally interpreted, taste perception may be a major clue for a specific choice: bitterness might be an indicator of bioactive compounds. But taste thresholds vary individually and culturally both in human and non-human primates (Huffman 1997). Plants secondary compounds are foremost a defence against herbivores. A bitter taste is usually an indicator of their presence. Ingested in small quantities, i.e. below the toxic threshold, the beneficial may outweigh the toxic effects. Not only does this balance depend on the component itself but also on the individuals age, body size and its ability to detoxify the compound, i.e. liver function (Masi 2012). Some criteria such as taste, smell or texture as criteria for the selection of plants are shared between chimpanzees and humans, those perceptions are rooted deep in our common primate history (Krief 2015, Huffman 2015).

When we consider health as a continuum, then the positive feedback of a medical substance may act as reinforce during the sampling of the regular diet by an individual that feels weak discomfort (Krief 2006).

Although case studies are uncommon, there is evidence suggesting that sick chimpanzees select peculiar food items, which are not consumed by the healthy individuals of the group (Krief 2015). Further studies are needed to find out whether curative self-medication is limited to parasitic diseases or not.

Padhi suggested ethno-directed sampling most likely to be successful in identifying drugs used in the treatment of gastrointestinal, inflammatory and dermatological complaints (Padhi 2013). And the most outstanding examples of chimpanzee self-medication and consistency with African traditional medical plant use are gastrointestinal issues.

Chimpanzees are our closest relatives and are often taken as models of human evolution, providing exemplary insight into the physiological, biological, psychological and behavioural origins of human conditions. We are driven by similar physiological mechanisms that respond to similar diseases and environmental pressures. Therefore there is a bio-rational for looking at chimpanzees for insights into the prehistoric plant use behaviour of humans (Huffman 2015). And yet we must not forget, chimpanzees are not genealogically our ancestors and our last common ancestor was neither an arboreal Hominid nor a quadrupedal chimpanzoid, but a far more primitive creature. And yet there is still a lot to learn from our closest sister species about the beginnings of our human medicine culture before artistic or written evidence.

Ingestion of plants with medicinal properties in not just a random event but an active decision and parasites have a significant impact on those foraging decisions (Huffman 2015,Krief 2006). Bitter Pith-Chewing at Mahale shows this exemplarily: *Vernonia amygdalina* is neither abundant nor evenly distributed in the forest. So ill individuals are observed taking detours and leaving their groups to seek treatment (Huffman 2016).

But not only African chimpanzees practice the art of self medication. In the central Kalimantan province in Indonesia, it is possible to observe a very rare behaviour of orang-utans (*Pongo pygmaeus*): self-medication using the bioactive properties of *Dracena cantleyi.* The Orang Utan bites of the apical part of the leaf and chews it into a pulp, releasing saponins to produce a white soapy lather. This lather is then rubbed on to the upper arm or upper leg. The remaining pulp is always spat put and never swallowed. A biological analysis of the leaves of *D. cantleyi* showed anti-inflammatory properties. Local indigenous people use crushed leaves for sore muscle and joints, for sore bones and swellings (Morrogh-Bernhard 2017).

Taking into account, chimpanzees having such a rich material culture, Theory of Mind, and a level of social learning that comes second to human, the chimpanzee pharmacopoeia must be more than two happy go lucky grips into the jungle.

Chimpanzees do not have the faculty of abstraction to construct medicinal systems based on religion or on an abstract theory of how the body works. Therefore, their medicine system is intrinsically free of any ideology whatsoever. And yet are their cognitive functions developed enough to make a connection between the ingestion of a certain plant or combination or another item and the relive of an existing symptom, whether it is on purpose or happened by chance. Those two facts should be taken into account by ethnobotanists and they should include great apes in their work as an unbiased third party whenever they have the chance to.

From an ethnobotanical view, the more cultures a given plant use, the more likely it is that it contains a physiological activity (Huffman 2003). Chimpanzees and other great apes contribute another piece of knowledge together with collected data of human plant use and in vitro data.

5 Literature

1. **Berlin, B., Breedlove, D., Raven. P.H.** (1973) General Principles of Classification and Nomenclature in Folk Biology. American Anthropologist 75 (1) 214-242.
2. **Call, J., Tomasello, M.** (2008). Does the chimpanzee have a theory of mind? 30 years later. Trends in Cognitive Science Vol. 12 No. 5
3. **Cock, I.E. (**2015). The safe usage of herbal medicines: counter-indications, cross-reactivity and toxicity. Pharmacognosy Communications Volume 54, Issue 1 Jan-Mar 2015
4. **De Waal, F.B.M.,** (1999). Cultural primatology comes of age. Nature 399:635-366
5. **Hardy, K., Buckly, S., Huffman, M.** (2013). Neanderthal self-medication in context. Antiquity 87: 873-878
6. **Huffman, M.A.,** (1997). Current Evidence of Self-Medication in Primates: A Multidisciplinary Perspective. Yearbook of Physical Anthropology 40:171-200
7. **Huffman, M.A.,** (2001). Self-Medicative Behaviour in the African Great Apes: An Evolutionary Perspective into the Origins of human Traditional Medicine. BioScience 51:8: 651-661
8. **Huffman, M.A.,** (2003). Animal self-medication and ethno-medicine: exploration and exploitation of the medicinal properties of plants. Proceedings of the Nutrition Society, 62: 371-381
9. **Huffman, M.A.** (2016) An Ape's perspective on the origins of medicinal plant use in humans in Hardy, K. and Kubiak-Martens, L. (editors) Wild Harvest, Plants in the hominin and pre-agrarian worlds; Oxbow Books Oxford and Philadelphia
10. **Huffman, M.A.,** (2016). Primate Self-Medication, Passive Prevention and Active Treatment – A Brief Review. International Journal of Multidisciplinary Studies 3(2) 1-10
11. **Huffman, M.A., Spiezio, C., Scaravatti, A., Leca, J.-B.**, (2010). Leaf swallowing behaviour in chimpanzees (Pan troglodytes): biased learning and the emergence of group level cultural differences. Animal Cognition 13: 871-880
12. **IUCN and Red List of endangered species** http://www.iucnredlist.org. Pages on Pan troglodytes. Last accessed July 29, 2018
13. **Kaplan, H., Hill, K., Lancaster, J., Hurtado, A.M.** (2000). A Theory of Human Life History Evolution: Diet, Intelligence, and Longevity. Evolutionary Anthropology 156-185
14. **Kariuki, S.T., Kariuki, J.M., Mailu B,.M., Muchiri, D.R.** (2018). Isolation and characterisation of chemical compounds fro the plants, Phytolacca octandra (L.), Phytolacca

dodecandra (L'Herit) and Balanites aegptiaca (L.) commonly used to control schistosomiasis transmitting snails in Kenya. African Journal of Pure and Applied Chemistry 12(6) 38-41

15. **Krief, S., Martin, M.-T., Grellier, P., Kasenene, J., Sévenet, T.** (2004). Novel Antimalarial Compounds Isolated in a Survey of Self-Medicative Behaviour of Wild Chimpanzees in Uganda. Antimicrobial Agents and Chemotherapy 48:8: 3196-3199
16. **Krief, S., Hladik, C.-M., Haxaire, C.** (2005). Ethnomedical and bioactive properties of plants ingested by wild chimpanzees in Uganda. Journal of Ethnopharmacology 101 (2005) 1-15
17. **Krief, S., Daujeard, C. Moncel, M.-H., Lamon, Reynolds, V.** (2015). Flavouring Food: the contribution of chimpanzee behavior to the understanding of Neanderthal calculus composition and plant use in Neanderthal diets. Antiquity 89: 464-71
18. **Krief, S., Huffman. M.A., Sévenet, T., Hladik, C.-M., Grellier, P., Loisseau, P.E.** (2006). Bioactive properties of plant species ingested by chimpanzees (Pan troglodytes schweinfurthii) in the Kibale national Park, Uganda. American Journal of Primatology 68:51-71 (2006)
19. **Masi, S., Gustafsson, E., Saint Jalme, M., Narat, V., Todd, A., Bomsel, M.-C., Krief, S.** (2012). Unusual feeding behaviour in wild great apes, a window to understand origins of self-medication in humans: Role of sociality and physiology on learning process. Physiology & Behaviour 105: 337-349
20. **Massaba, S.C.** (2000). The antimalarial activity of Vernonia amygdalina Del (Compositae). Transaction of the Royal Society of Tropical Medicine and Hygiene (2000) **94,** 694-695
21. **McGrew, W.C.,** (2004) The Cultured Chimpanzee: Reflections on Cultural Primatology. Cambridge University Press
22. **McLennan, M.R., Hasegawa H., Bardi M., Huffman M.A.,** (2017). Gastrointestinal parasite infections and self-medication in wild chimpanzees surviving in degraded forest fragments within an agricultural landscape mosaic in Uganda. PloS ONE 12(7):e0180431
23. **McLennan, M. R., Huffman, M.A.** (2012) High Frequency of Leaf Swallowing and Its Relationship to Intestinal Parasite Expulsion in "Village" Chimpanzee at Bulindi, Uganda. America Journal of Primatology 74:642-650
24. **Mitani, J.C., Watts, D.P., Muller, M.N.** (2002). Recent Developments in the Study of Wild Chimpanzee Behaviour. Evolutionary Anthropology 11: 9-25
25. **Mittermeier, R.A., Rylands, A.B., Wilson, D.E.** Eds (2013) Handbook of the Mammals of the World Volume 3: Primates. Lynx Editions, Barcelona
26. **Morrogh-Bernard, H.C., Foitovà, I., Yeen, Z., Wilkin, P., de Martin, R., Ràrovà, L,. Dolezal, K., Nurcahyo, W., Olsansky, M.,** Self-medication by orang-utans (Pongo pygmaeus)

using bioactive properties of Dracaena cantleyi, Scientific Reports, 7:16653

27. **Moshi, M.J., Otieno, D.F., Mbabazi, P.K., Weisheit, A.** (2009). The Ethnomedicine of the Haya people of Bugabo ward , Kagera region, north western Tanzania; Journal of Ethnobiology and Ethnomedicine 2009 5:24
28. **Moshi, M.J., Otieno, D.F., Mbabazi, P.K., Weisheit, A.** (2010). Ethnomedicine of the Kagera region, north western Tanzania. Part 2: The medicinal plants used in Katoro ward, Bukabo District. Journal of Ethnobiology and Ethnomedicine 2010 6:19
29. **Moshi, M.J., Otieno, D.F., Mbabazi, P.K., Weisheit, A.** (2012). Ethnomedicine of the Kagera region, north western Tanzania. Part 3: plants used in traditional medicine in Kikuku village, Muleba District. Journal of Ethnobiology and Ethnomedicine 2012 8:14
30. **Owen Lovejoy, C.** (2009). Reexamining Human Origins in Light of Ardipithecus ramidus. Science Volume 326 74
31. **Padhi, L., Panda S. K.** (2013). Medicinal plants: Potential to fight superiority diseases. Annals of Pharma Research
32. **Premack, D., Woodruff, G.** (1976) Does the chimpanzee have a theory of mind? The Behavioural and Brain Sciences (19/8), 4 515-526; 1978 Oxford University Press
33. **Rendell L., Fogerty, L., Hoppit W.J.E., Morgan T.J.H., Webster M.M., Laland K.N.,** Cognitive Culture: theoretical and empirical insights into social learning strategies. Trends in Cognitive Science 2011 (15/2) 68-75
34. **Schlinger, H.D.,** (2009). Theory of mind: an overview and behavioural perspective. The psychological Record, 2009, 59, 435-448
35. **Villalba, J.J., Miller. J., Ungar, E.D., Landau, S.Y., Glendinning, J.,** Ruminant self-medication against gastrointestinal nematodes: evidence, mechanism, and origins; Parasite 2014, **21**, 31
36. **Weckerle, C.S.**, et al, 2012, unpublished research plan
37. **White, T.D., Asfaw, B. Beyene, Y., Haile-Selassie, Y. Owen Lovejoy, C., Suwa, G., Wolde Gabriel, G.** (2009). Ardipithecus ramidus and the Paleobiology of Early Hominids, Science Volume 326 64
38. **Whiten, A., Goodall, J., McGrew, W.C., Nishida, T., Reynolds, V., Sufiyama, Y., Tutin, C.E.G., Wrangham, R.W., Boesch, C.** (1999). Cultures in Chimpanzees. Nature 399: 682-685
39. **Whiten, A., van de Waal, E.** (2018) The pervasive role of social learning in primate lifetime development. Behavioural Ecology and Sociology 72:80