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Authors: Wadley, Greg, and Hayden, Brian

Source: Journal of Ethnobiology, 35(3) : 566-584

Published By: Society of Ethnobiology

URL: https://doi.org/10.2993/etbi-35-03-566-584.1

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Journal of Ethnobiology 35(3): 566–584 2015

PHARMACOLOGICAL INFLUENCES ON THE NEOLITHIC TRANSITION

Greg Wadley[1*] and Brian Hayden[2]

While uncertainty remains as to the relative importance of the factors that propelled Neolithization at different sites, a model is gaining traction that proposes that cereal cultivation was adopted in part to produce alcohol for competitive feasting. The model ties together the emergence of two key phenomena – cereal cultivation and social inequality – and is supported by a variety of archaeological and ethnographic data. However pharmacological theory has not yet been explicitly deployed in the presentation of the model; rather its development has relied on a common-sense understanding of the effects of alcohol and its cross-cultural importance in social life. Our aim in this paper is to bring understandings of drug use from pharmacology and related disciplines to bear upon the challenge of explaining Neolithization. We find that pharmacological theory sheds light on the importance of alcohol and other mood-altering products of Neolithic farming. In particular there is support for some influence of pharmacoactivity on Neolithic social evolution, which might extend beyond a role in feasting to include modulation of responses to status hierarchies, increased residential densities, and more intense work schedules. We propose that pharmacological influences be incorporated into models of the Neolithic transition.

Keywords: *Neolithic transition, complex societies, pharmacology, alcohol, feasting*

Introduction

The change from a long-standing hunter-gatherer lifestyle to one based on farming and sedentary life in large, hierarchical societies began at a handful of primary sites and spread via movements of people, species, and ideas until it transformed much of the human world. While new data continue to shed light on how and when Neolithization occurred, uncertainty remains about why people chose to undergo this major change in subsistence and social behaviors. Evidence that early cereal farming did not necessarily lead to improved nutrition and population health (Bowles 2011; Cohen 1989) led many researchers to reject the "pull factor" of "a highly desirable and welcome invention providing security and leisure time for prehistoric peoples" (Price and Bar-Yosef 2011:S166) in favor of "demand-, need- or push-based" motives (Cohen 2009:591) such as climate deterioration or population pressure.

A hypothesis that is attracting increasing interest proposes that Epipaleolithic populations exploited and then cultivated cereals, not primarily for food but to brew alcohol for use in competitive feasting. An early partial version of this hypothesis was proposed by J. D. Sauer (Braidwood et al. 1953) and later

[1] Department of Computing and Information Systems, The University of Melbourne, Parkville 3010, Australia
[2] Archaeology Department, Simon Fraser University, Burnaby, BC V5A 1S6, Canada
* Corresponding author (greg.wadley@unimelb.edu.au)

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elaborated by Katz and Voigt (1986). Recently Hayden and colleagues (2012) provided archaeological evidence for this hypothesis, as one component of Hayden's (1990) "competitive feasting" model. In this view, aggrandizing individuals used alcohol to attract people to feasts and then to manipulate them to acquire political power via reciprocal feasting debts. This "alcohol model" when combined with feasting models explicitly addresses the co-occurrence of two key Neolithic phenomena – cereal agriculture and social inequality – and is supported by a range of archaeological and ethnographic data (Hayden et al. 2012). However, pharmacological theory has not yet been explicitly deployed as part of the model; rather it has relied upon a common-sense understanding of the effects of alcohol and its role in social life. The purpose of this paper is to use insights from pharmacology and related disciplines to explore, in more depth, the role of alcohol and other pharmacologically active comestibles in Neolithization such as coca, poppy, and tobacco. In our view, such crops probably constituted one of the important components of early aggrandizer "toolkits" for creating differential power. Recognizing a pharmacological role in Neolithization helps to explain the choice of these species for cultivation and contributes to a more nuanced understanding of the dynamics of Neolithization.

The Neolithic Transition

The earliest known Neolithic transition and one of the best studied occurred in the Pre-Pottery Neolithic (PPN) in the southern Levant (Kuijt and Goring-Morris 2002). Climate change during the Epipaleolithic may have led to the appearance of large local stands of wild cereals, possibly cultivated by Late Epipaleolithic (Natufian) bands (c. 14,500-11,700 BP) and PPNA communities (11,700 to 10,500 BP) without creating genetic changes (Willcox et al. 2008). During the subsequent PPNB (10,500 to 7800 BP) this area saw the morphologically manifested domestication of cereals, sheep and goats, the concentration of populations into permanent villages that grew dramatically in size, and a reorganization of political and economic structures and processes (Kuijt and Goring-Morris 2002). While particular circumstances and species varied, broadly similar processes occurred at many sites globaly (Cohen 2011).

Neolithization involved not only new subsistence practices, but also a change in the size and structure of human groups. While simple mobile band societies probably consisted of 15-40 individuals living in egalitarian relationships in which food and materials were generally shared, by 12,000 BP some Natufian hunter-gatherer communities had become sedentary or semi-sedentary and were comprised of up to 200-300 people who recognized private property, held wealth, and exhibited socioeconomic differences (Hayden 2004, 2011a; Henry 1989:214; Perrot 1966:477). Subsequent PPNA villages such as Jericho had up to 200 inhabitants or more living close together (Goring-Morris and Belfer-Cohen 2011). Some settlements in the PPNB reached town proportions covering areas up to ten hectares (Twiss 2008) with populations at least in the hundreds and probably much higher (Goring Morris and Belfer-Cohen 2011). However, there were a number of negative effects that accompanied reliance on domesticated plants. Populations increased in spite of the likely detrimental effects of new diets

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(Cohen 1989). Greater densities must have created scalar stresses (Friesen 1999) and fomented greater competition between and within sites, evidenced by an increase in violence in the PPNB (Belfer-Cohen and Goring-Morris 2011).

Hayden and colleagues (2012) emphasized the risks involved in the long delay between agricultural effort and payoff, such as drought, pests, and theft. Cultivation is a delayed-return investment (Winterhalder and Kennett 2009) whose potential nutritional payoff should be discounted because unforeseen events might reduce its future availability (Cohen 2009; Tucker 2006). Future-discounting is a rational and probably universal practice (Green and Myerson 2004) and it has been suggested that a key difference between forager and farmer lifeways concerns the degree to which each accepts, and is willing to discount, delayed returns (Woodburn 1988).

The most common explanations for the social changes emerging from domestication involve chains of causality in which environmental and population pressures led to crises that forced people to adopt cultivation and participate in complex societies, which then enabled specialization and technological advances, empowering these groups to dominate others (Cohen 1975; Rosenberg 1990). However, the high risks, lower returns, and nutritional disadvantages of cultivation do not seem to support exclusively subsistence-oriented explanations of domestication. Moreover, a link between population pressure and domestication or cultivation is far from certain (Hayden 2000, 2014). The assertion that sedentism produces complex societies is also problematic, since some hunter-gatherers became sedentary without developing social complexity (Kelly 1992), and conversely, there are highly mobile societies, such as pastoral nomads, that have developed chiefdoms and even empires.

Thus we suggest that other factors should be considered which may help explain changes in both sustenance strategies and social structures. Hayden (1990, 2009, 2011b, 2014), for example, has argued from ethnographic and archaeological evidence that cultivation was motivated by the advantages that competitive feasting provides in building political power and pursuing self-interests. Feasting and political gift economies are common among ethnographically described complex human societies including complex hunter-gatherer but not those employing a simple foraging lifestyle characterized by sharing and egalitarianism. Partly through the agency of psychoactive substances, feasts in traditional societies are, and presumably were, used as arenas for inculcating ideologies, creating cohesion and social differentiation within a social group, and introducing new foods and technologies (Dietler 2001; Hayden 2014; Twiss 2008). Feasts require the production and storage ahead of time of large quantities of food and drink, and successful organizers can and do obtain political power and reproductive success (Hayden 2009, 2014). The social competition model proposes that a *wealth* rather than a dearth of resources enabled people to engage in high risk production activities such as cultivation and domestication. In this scenario, a failure of food production for feasts could not affect basic subsistence, but success would provide important sociopolitical advantages. Neolithic domesticates are proposed, in part, to have been used as costly status symbols, helping to bring an end to egalitarianism largely via feasting.

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Since consumption of alcohol is a primary component of Neolithic feasting (Twiss 2008), one might expect that producing alcohol for feasts could have been a significant motivator of attempts first at harvesting, and eventually, at cultivating cereals. Noting the possible cultural significance of cereals for making alcohol in the Epipaleolithic, Katz and Voigt (1986:28) suggested that "any disruption in the supply of these wild foods would have posited a serious problem" which could have been resolved by cultivating cereals. Smalley and Blake (2003) made a similar point regarding the domestication of maize in Neolithic America, arguing that, initially, the primary use was to produce alcohol, the importance of which drove the rapid diffusion of this cereal. Hayden and colleagues have recently presented evidence that Levantine and East Asian pre-farming and farming groups were producing alcohol (Hayden 2011a; Hayden et al. 2012). These authors describe ancient brewing techniques in detail and propose a method for brewing given the available technology and testing it experimentally.

In order to flesh out these models in a broader pharmacological context, we first review the production of alcohol and other psychoactive domesticates by Neolithic farmers with a focus on their behavioral effects. We do not discount the nutritional aspects of agriculture, but acknowledge and attempt to explain the high representation of psychoactive plants among early crops.

Psychoactive Crops

A psychoactive substance influences thought or emotion through biochemical action upon the nervous system. When exogenous they are commonly referred to as "drugs," but as Sherratt (1995a) has argued, this term carries controversial and variable cultural meanings and a morally neutral term is preferred. In pre-Industrial times, drugs were usually ingested as part of a food or drink, so that effects on mood could be confused with nutritional benefits (Hagen et al. 2013); thus Jankowiak and Bradburd (1996) used the term "drug foods." However, not all drugs are consumed by an oral route, and we have followed Sherratt in using the term "psychoactive substances," abbreviating it to PAS.

The use of PAS precedes agriculture and was widespread in forager societies (e.g., Saniotis 2010:481; Thomas 2003). Many PAS were exploited for medicinal purposes (Guthrie and Ho-Yen 2011) or were mild stimulants, including tobacco in America and Australia, and khat and betel in Africa and Asia (all these plants were eventually cultivated by some groups). Much forager PAS use focused on hallucinogens for ritual purposes, such as to induce shamanic trances and communicate with the spirit world (La Barre 1970; Merlin 2003:295; Van Pool 2009). Most hallucinogens are debilitating in high doses, and their powerful effects deter widespread consumption, restricting use largely to infrequent rituals by a few specialists. With domestication, however, the focus shifted from perception-altering to mood-altering, euphoric, or stimulating PAS (Merlin 2003). Domestication enabled the production of large and reliable quantities of such PAS (Saniotis 2010; Sullivan and Hagen 2002). In the primary Neolithic sites, West and East Asian farmers produced alcohol, while American farmers

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Table 1: PAS production by early farmers

Geographical area	Psychoactive crops	Sites
West Asia (Levant, Mesopotamia)	Cereals for alcohol (Hayden et al. 2012; McGovern 2009)	Abu Hureyra (Hillman et al. 2001) (11,000 BCE) Jerf el Ahmar (Willcox 2007; Willcox et al. 2008, 2009) (9500 BCE) Gobekli Tepe (Dietrich et al. 2012) (9000 BCE)
East Asia (China)	Rice for alcohol (Hayden 2011b; McGovern et al. 2004)	Jiahu (Roach 2005) (7000 BCE)
	Cannabis (Merlin 2003)	Yang-shao (Li 1974) (4000 BCE)
	Tea (Li 1983)	Yunnan or Sichuan province (400 BCE?)
Central America (Mexico)	Maize for beer (Smalley and Blake 2003)	Early Formative (1600 BCE)
	Tobacco (Groark 2010)	Classic (500 CE)
	Cacao (Henderson et al. 2007)	Puerto Escondido (1000 BCE)
South America (Andes)	Coca (Dillehay et al. 2010)	Nanchoc Valley (6000 BCE)
	Maize for beer (Benz and Staller 2006; Tykot and Staller 2002).	La Emerenciana (2200-2000 BCE)
North America (Late Archaic and Early Woodland)	Tobacco (Rafferty 2006; Tushingham et al. 2013)	Vermont (500 BCE) Pacific Northwest (860 CE)
	Maize and tobacco (Fritz and Kidder 1996; Knight 2001; Lindauer and Blitz 1997; Reber 2006; Wymer 1994)	Southeastern U.S. Early Woodland platform mounds (100 BCE-800 CE)
Europe	Cereals for alcohol (Sherratt 1995a)	Late Neolithic (3500 BCE)
	Poppy (Zapata et al. 2004)	Spain, Mediterranean (5500 BCE)
	Cannabis (Merlin 2003)	Various sites from 500 BCE (refs in Merlin 2003)
India	Cereals for alcohol (Fuller 2005)	Southern Neolithic (1500 BCE)
	Cannabis (Touw 1981; Zohary et al. 2012)	1000 BCE
Africa (East, West)	Coffee (Anthony et al. 2002)	Ethiopia, Kenya, Sudan (500 CE)
	Kola (Lovejoy 1980)	Guinea (<1500 CE)
Melanesia (New Guinea)	Sugar cane (Denham 2011; Grivet et al. 2004)	New Guinea highlands (6000 BCE?)

produced alcohol, coca, tobacco, and cacao (see Table 1). European and Asian farmers added opium and cannabis to the Levantine crop complex; in Southern India farmers produced grains for alcohol; in Africa, coffee and kola were major trade items. Sherrat (1995a) and other authors have illustrated the global importance of PAS to farming societies. Table 1 lists the major Neolithic regions and the PAS produced there.

Mood-altering PAS stimulate brain reward pathways (Blum et al. 2012). They are highly prized and sought for effects such as amicability, reduction of stress, and feelings of liberation. They are widely used in many cultures, and they have been major trade goods throughout history and prehistory. Psychoactive substances were not the only products of early cultivators, but they were typically the most highly valued and were given religious and social significance.

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Even today, the majority of adult humans regularly use PAS derived from early domesticates including alcohol, nicotine, caffeine, chocolate, and sugars (Anderson 2006). Ancient users may not have perceived these as drugs in the modern sense but simply as desirable, good tasting, good feeling foods (McGovern 2009; Sullivan and Hagen 2002). In early modern times, PAS played a facilitating role in global colonization, used first to entice indigenous peoples into labor arrangements, and then to reward individuals for labor and production outputs (Courtwright 2009). The effects of PAS upon mood and motivation are critical: "Habitual users tend to develop psychological or physiological dependency on them and, in turn, on the trader or merchant who provides them," (Jankowiak and Bradburd 1996).

Alcohol

Ethyl alcohol was probably first produced by West Asian Epipaleolithic cereal foragers (Hayden et al. 2012) as well as by complex hunter-gatherers and early farmers in China 9000 years ago (McGovern et al. 2004), in Central America 6,000 years ago (Smalley and Blake 2003), in Incan South America (Staller 2009), and in Neolithic India where the purpose of growing wheat and barley in some areas seems to have been to produce alcohol (Fuller 2005). Alcohol has had an enormous impact on social and religious practices around the world (Sherrat 1995b). It played a major role in public and private life in most of the major early civilizations, where it was consumed at religious, political and social events (Jennings et al. 2005).

Nicotine

Tobacco was gathered and cultivated in America as early as 4000 years ago (Rafferty 2006) and was used for religious and social rituals, as medicine, and for trade and recreation (Groark 2010; Wilbert 1979). While tobacco was probably originally used exclusively by shamans, with cultivation it became more democratized (von Gernet 1995). After domestication in the Andes (Pickersgill 2007), tobacco spread to Central America (Groark 2010) and then into North America as a domesticate along with maize at least two thousand years ago (Rafferty 2006).

Caffeine and theobromine

Caffeine is a psychostimulant and antidepressent (Pechlivanova et al. 2012) and is currently the world's most widely used PAS (Weinberg 2000). Coffee was first exploited in East Africa at least 1500 years ago (Anthony et al. 2002), kola in West Africa at least 500 years ago (Lovejoy 1980), and tea in China at least 2,000 years ago (Li 1983); all were socially important and were major drivers of agriculture and trade.

A drink of fermented cacao (which contains not only caffeine but the pharmacologically similar theobromine) was in use over 2000 years ago in Central America (Henderson at al. 2007; Powis et al. 2002) and may have been the key trade product that enabled the Olmec to create expansive early complex polities in Mesoamerica. Subsequently, chocolate was used in social and ritual settings by the Mayans and served as a currency and elite drink for the Aztecs.

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Cocaine

There is evidence for coca use as early as 8000 years ago in northern Peru, so it was "a feature of the rise of agriculture and social complexity in the region" (Dillehay et al. 2010). By the time of the Incan civilization, coca was a marker of social status and was accorded religious significance (Plowman 1984).

Cannabis

Cannabis was one of the earliest PAS used in India and was part of the early Chinese Neolithic crop complex (Merlin 2003). It was also one of the few domesticates in Early Jomon Japan (Crawford 1983:23-25). Charred seeds found in pots throughout Eastern Europe indicate that cultivation spread there soon after initial domestication (Rudgley 1995).

Opiates

The opium poppy is native to Mediterranean Europe and was probably the first plant added to the crop complex imported from the Levant (Zapata 2004). Poppies, cereals, and pulses formed the plant assemblages of the first farmers in Italy (Merlin 2003), and opioids have been found in the bones of Neolithic miners as well as at burial sites in Iberia (Zapata 2004).

Sucrose

Humans eat sweet, fatty, energy-dense foods in response to depression, stress, and negative affect (Gibson 2012). These "comfort foods" (Dube et al. 2005) induce "a psychologically comfortable and pleasurable state for a person," (Wansink et al. 2003). Sucrose acts as an analgesic (Blass et al. 1987), reduces stress (Ulrich-Lai et al. 2010), and reduces future discounting (Wang and Dvorak 2010), with repeated consumption leading to tolerance and withdrawal effects (Johnson and Kenny 2010).

Sugar cane appears to have been first used at least 6000 years ago in New Guinea (Daniels and Daniels 1993; Denham 2011), and its cultivation and use later spread throughout Asia (Galloway 2005) into Europe, where it was a major driver of European colonization and trade (Grivet et al. 2004).

Dietary peptides

Both the neurotransmitter serotonin and its precursor tryptophan influence mood (Young 2007). Kerem et al. (2007) showed that chickpea, a Levantine founder crop, contains a high level of tryptophan which increased with domestication, suggesting that early farmers selected and were able to discriminate high tryptophan varieties. Kerem et al. (2007) argued that mood effects motivated cultivation and may have become important in early agricultural communities.

Opioid peptides called exorphins are produced when cereals and milk are digested (Zioudrou et al. 1979), and it has been proposed that this contributed to the attractiveness of some domesticates (Wadley and Martin 1993). Most pharmacological evidence for their effects comes from animal models where exorphins raise pain thresholds (Gritsai et al. 2009), reduce anxiety (Belyaeva et al. 2008), and interfere with satiety signaling leading to increased food intake

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(Duraffourd et al. 2012). Their function in humans is less understood, though current research is exploring a role in mental health conditions (e.g., Sokolov et al. 2014).

Summary

The extensive early production of psychoactive substances has been widely discussed in anthropological and archaeological literature, yet pharmacological research has rarely been drawn upon for clues as to how PAS might have influenced ancient users. We believe that a comprehensive archaeological explanation of PAS cultivation and domestication should include discussion of the psychosocial roles of these substances, a topic addressed next.

Understanding Psychoactive Substance Use

Psychoactive substances shape behavior by influencing mood and motivation (Nesse and Berridge 1997), future-orientation (Giordano et al. 2002), and social behavior (Velea and Hautefeuille 2007). While early pharmacological research focused on mechanisms underlying *compulsive* use of psychoactives, recent work has offered a more nuanced understanding, with researchers arguing that much PAS use is not the result of addiction per se, but that it serves instrumental purposes such as coping with stress or fatigue (Morgan et al. 2013), alleviating psychological distress (Pickard 2012), and achieving work or social goals (Muller and Schumann 2011). Benefits include feeling part of a social group, enjoyment, creativity, relief of pain and anxiety, relaxation, control of waking and sleep cycles, improved memory and concentration (Morgan et al. 2013), and, in some cases, maintaining neurotransmitter levels (Hagen et al. 2013). This section reviews current understandings of why PAS are used and how they influence behavior.

Motivation and Emotion

PAS activate brain pathways that regulate appetitive anticipation and consummatory hedonia (satisfaction upon attainment) (Berridge and Robinson 1998; Blum et al. 2012). From a Darwinian perspective, they provide artificial subjective rewards that create "a signal in the brain that indicates, falsely, the arrival of a huge fitness benefit" (Nesse and Berridge 1997). Nevertheless, PAS lead the user to attribute importance to settings and events associated with PAS (Lende and Smith 2010), and to crave repeated use (Robinson and Berridge 1993).

Several avenues of research show that PAS influence individuals' perceptions of, and abilities to deal with, social situations. Pro-social behavior is facilitated through reduction of anxiety, enhancement of self-confidence, suppression of fatigue, and disinhibition of communication (Muller and Schumann 2011:298). Nicotine (Todd 2004), alcohol (Cooper et al. 2002), and other PAS (Sinha 2001) counter social stress, while alcohol is used for mood enhancement, cognitive performance, and to reduce symptoms of depression (Muller and Schumann 2011).

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Empathogens such as MDMA increase sociability and make identification of social threat less accurate (Bedi et al. 2010). Many feasting foods such as alcohol, kava, betel, nicotine, and fatty meat have the same effect (Dietler 2001; Hayden 2014). Enjoyment of social interaction is enhanced by exogenous opioids (Trezza et al. 2011), and alcohol is used to remedy an inability to interact socially (Martinotti et al. 2009).

Psychoactive substances can reduce the subjective stress of living in groups, so that "social constraints become bearable and the individual feels independent while remaining within society" (Velea and Hautefeuille 2007). People and animals become stressed if they feel crowded (Armario et al. 2008; Calhoun 1973; Epstein 1981). Crowding stress is mediated by serotonin (Daniels et al. 2000) and attenuated by anti-depressants (e.g., Naitoh et al. 1992), alcohol (Nagaraja and Jeganathan 2003), opiates (Xigeng et al. 2004), and high-caloric food (Coccurello et al. 2009).

Artificial rewards are particularly attractive to those who have fewer opportunities to receive natural rewards (Nesse 2002) that lead to increased fitness, e.g., people with low socio-economic status (Anderson 2006). Social defeat precipitates use of PAS by animals (Bardo et al. 2013:276-280), including cocaine (Haney et al. 1995) and alcohol (Hilakivi-Clarke and Lister 1992; Wolffgramm and Heyne 1991), and heavy use in humans is likely due to similar situations. In addition, comfort foods are used to address effort-reward imbalance (Kouvonen et al. 2005b) that arises when physical or mental effort is not commensurate with pay and social rewards (Siegrist 1996).

Delay of Gratification and Willingness to Work

Future-discounting, or impulsiveness, refers to an individual's preference to receive immediate return or instant gratification rather than to apportion effort now for future payoff. Future-discounting is not irrational but represents recognition of the risk that a delayed payoff may not materialize to the extent desired or even at all; thus all individuals future-discount to varying extents (Green and Myerson 2004).

Future-discounting is influenced by PAS in a complex fashion. While some users are more impulsive than non-users (Bickel and Marsh 2001), impulsiveness may both be a cause and a consequence of PAS use (Stein and Madden 2012). In addition, PAS use can increase an individual's ability to delay gratification by offering an immediate false reward substitute for a delayed real fitness reward. PAS can reduce impulsiveness by inducing a feeling of power over the delivery of reward (Soubrie 1986). For example, opioid users who are currently sated discount less than do those currently deprived (Giordano et al. 2002), and individuals who have recently consumed sucrose-laden drinks are more likely to accept delayed rewards (Wang and Dvorak 2010).

PAS have been used throughout history to inhibit work-related stress, to overcome muscle and mental fatigue, to adapt to work environments, and to enhance work performance (Courtwright 2009; Dube et al. 2005; Grunberg et al. 1999; Jankowiak and Bradburd 1996; Kivimäki et al. 2006; Kouvonen et al. 2005a; Muller and Schumann 2011). Tellingly, Muller and Schumann (2011) consider high workloads in industrial societies to be a major driver of contemporary PAS use.

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Summary

Psychoactive substance use does not represent merely a problematic behavior indulged in by a minority; rather it is an important and routine shaper of behavior for the vast majority of post-Neolithic humans. Is this mere coincidence, or is there a causal link between widespread adoption of mood altering PAS and the emergence of Neolithic cultures? PAS induce pro-social behavior and conformity to social constraints, and reduce scalar, work, and status-related stress. Thus, PAS should promote tolerance of larger, more impersonal social structures and the behaviors required of individuals participating in them (Muller and Schumann 2011; Nesse 2002; Velea and Hautefeuille 2007). They provide substitute rewards in the present that facilitate commitments to work for uncertain future rewards, and they are used to elicit appropriate emotional responses during work. Over the millennia, sociopolitical and economic organizers have promoted their use by workers.

A Pharmacological View of the Neolithic Transition

Considering the prominence of crops that could produce PAS in early farming assemblages, and the profound influences that PAS have upon social and individual behavior, we now explore the potential for pharmacological theory as an explanatory factor in understanding Neolithization. Our exploratory model has two facets: 1) that cultivation was adopted in part to establish more reliable supplies of PAS, and 2) that the PAS thus obtained helped to facilitate changes in social structures and behaviors that characterize the Neolithic phenomena.

A Motive for Cultivation

The alcohol model of Braidwood et al. (1953), Katz and Voigt (1986), and Hayden et al. (2012) proposes that a desire for the hedonic effects of this PAS and its enabling role in feasting and ritual drove intensive gathering and then cultivation of plants from which alcohol is derived. It is often assumed that cereals were cultivated in order to make bread, although the use of maize in South America is often viewed as having been adopted primarily to produce beer (Tykot and Staller 2002; Benz and Staller 2006). The same may have been true in the Neolithic Levant, although bread may have also had mood altering qualities due to its high glycemic index and other characteristics (Hayden et al. In press). The alcohol hypothesis is supported by pharmacological theories of artificial reward (Nesse and Berridge 1997), and is easily extensible to the cultivation of other psychoactive cultigens such as poppy, coca, coffee, cacao, tobacco, and cannabis. It is very likely that these plants were cultivated primarily for their pharmacological effects. Cultivation made psychoactive substances more available, more regularly and more reliably, to more people. Demand for PAS would have increased substantially with the appearance of competitive feasting among complex hunter-gatherers, where PAS would have been used to attract and obligate people in ways that promoted the power of successful feasters and their supporters. Space constraints limit our documentation of competitive feasting

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among complex hunter-gatherers prior to domestication, but the Northwest Coast potlatch provides a well-known example. Detailed documentation is provided in Hayden (2014).

Cultivators whose efforts were focused on crops with great PAS effects but little nutritional value would have had to rely on foraging and hunting for food, in some cases for very long periods; this is consistent with the archaeological record (Flannery 1973; Fuller et al. 2009; Smith 2001; Tanno and Willcox 2011). However, in the long run, crop complexes that yielded both psychocoactive *and* nutritional products, such as the Levantine, East Asian, and American cereal-based systems, ultimately were able to dominate entire regions.

Social Structures and Behavior

There can be little doubt regarding a correlation between PAS use and increasing social complexity, nor of the importance that early civilizations placed upon the consumption of PAS (Goodman et al. 1995; Groark 2010). The question we address is whether there is a *causal* relationship between social complexity and PAS use.

Politically ambitious individuals may have promoted regular PAS use, and PAS use could have substantially advanced political agendas. An increased ability to manipulate people would be a powerful tool in the hands of an aspiring leader, and ambitious leaders probably competed in the use of such tools, offering more, better quality, and newer varieties of PAS (cf. King et al. 2009). In particular, because PAS were highly desired by many people, the ability to supply PAS could facilitate the ambitions of individuals by helping to lure people into relationships involving debts, favors, and political power as part of competitive feasting (Hayden 2014). Increased compliance stemming from PAS use among some of a community, combined with intense competition by a few for leadership positions, could act to engender a hierarchy of political classes. Once political control began to appear in this context, PAS use could amplify social differences by attracting people to obtain PAS, creating acquiescence, and providing solace via PAS use for those holding lower status positions in a society that was becoming increasingly hierarchical.

Hayden (1993, 2003) has argued that the distinctive human adaptation lies not in physiology or intelligence, nor even tool use, but in an emotional adaptation to social living and the use of social skills to access food, security, dominance, mates, and success in competitive interactions. This perspective is also advocated for by Gowlett et al. (2012). The use of psychoactive substances to manipulate social relationships is likely to be part of this distinctive adaptation. Ethnographic accounts almost always associate PAS use with social acts: often the bringing together of family, friends, factions, allies, or other support personnel (e.g., Goodman et al. 1995).

Conflict is a significant contributor to forager mortality (Gat 2006), and it is no surprise that conflict also afflicted agricultural settlements as they reached higher densities (Belfer-Cohen and Goring-Morris 2011); yet within-group conflict and violence among agriculturalists was not so great as to prevent stable sedentary polities from persisting. PAS use would have helped communities to grow and become more stable by increasing people's tolerance

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of large group conditions (Coccurello et al. 2009; Nagaraja and Jeganathan 2003; Xigeng et al. 2004). By enhancing pro-social behavior, PAS use would help to bind a larger group together, including inducing commitments to future physical confrontations with other groups. This would help agricultural societies to compete more effectively than foraging groups who lacked the organizational framework and group sizes critical for winning conflicts.

Complex Labor Arrangements

The idea that the provision of PAS facilitates complex labor arrangements is not new. Staller (2009) noted that maize beer was used to pay workers and was a key element in keeping the Incan state functioning. Morris (1979) quoted a chief's 1556 testimony that "the main reason that the people obey their leaders here is through the custom that they have to give the people drink." Aztec leaders too provided alcohol to their subjects and controlled the quantities consumed (Mitchell 2004). Egyptian, Sumerian, and probably most other Near Eastern states paid their workers partly in beer (Jennings et al. 2005). Jankowiak and Bradburd (1996) and Courtwright (2009) argued that drug foods have likewise been a globally important tool of colonizers, operating to induce natives to engage in labor and then used to increase their work efficiency, intensity, and duration. Contemporary Amazonian elders provide coca to farm workers in a manner comparable to the coffee or cigarette break that characterizes labor in the West (Hugh-Jones 1995). Cameron and Jones (1985) described a political function for "drugs of solace" in terms of maintaining working class compliance. Our model simply locates the origin of this strategy earlier within the Neolithic and at a smaller, more localized scale.

Discussion and Conclusion

Extensive archaeological evidence shows that a significant portion of the effort of early cultivators globally was probably directed to the production of psychoactive substances (PAS), including the use of cereals, poppies, coca, sugar cane, tobacco, and cannabis. We propose a model involving PAS in two phases of Neolithication. First, people were attracted to PAS, and accorded them prestige because of their rewarding, mood-altering properties. Second, as cultivation enabled PAS use to become widespread and regular, the power of PAS to influence social behavior helped to create and reinforce complex social structures by inducing acceptance of crowded conditions, heirarchical power, and regular, hard work for others. Hayden et al. (2012) concluded that "feasting and brewing very likely provided a key link between increasing "complexity" and the adoption of cereal cultivation." The pharmacological theory presented here supports and enriches this hypothesis and supplies a mechanism for the link. Importantly, it gives the model broader range, as it can be applied to PAS other than alcohol, and thus to more cases of Neolithization.

Enhancing models of Neolithization with pharmacological theory provides compelling causality for the cultivation of PAS crops, and some crops, like cereals, that are usually assumed to have had only subsistence value. When combined with the emergence of complex hunter-gatherers exhibiting feasting

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and other strategies for controlling labor (ancestor worship, bride prices, material ritual requirements), pharmacology can provide a more powerful explanatory framework for the emergence of increasing social complexity.

Although foreshadowed by developments in complex hunter-gatherers, we propose that a major component of the Neolithic transition was a pharmacological transition consisting of a change in the kinds of psychoactive substances consumed (from shamanic use of hallucinogens to mood-altering PAS), the quantity and frequency of consumption, the ways they were produced, and the range of people who consumed them. The production of PAS crops represented supplemental work beyond mere subsistence needs, and therefore generally would have been undertaken by those with subsistence surpluses and greater access to labor. For example, the production of beer from grain was predicated on a surplus production of grain beyond subsistence needs that only the relatively wealthy could afford (Arthur 2003; Dietler 1990; Jennings et al. 2005). Thus, it would have predominantly been wealthy and highly motivated individuals who produced, controlled, and used PAS to advance their political strategies, generally via cultivation and the hosting of feasts.

Our reasoning is applicable to both fully agricultural and mixed-strategy groups, and can help to explain both primary Neolithization and its spread from initial sites of cultivation and domestication. It is compatible with the proposed extension of optimal foraging models to include the prestige associated with particular items including special foods (Hayden 2009, 2014; Winterhalder and Kennett 2006). Finally it can help explain why only crop complexes that produced foods both with PAS and subsistence value resulted in the formation of large-scale polities. Thus pharmacology belongs, we believe, among the factors from which accounts and models of early cultivation are constructed.

Acknowledgments

Greg Wadley would like to thank Prof. Angus Martin of the University of Melbourne for discussion and advice. Brian Hayden's research on feasting was supported by the Canadian Social Sciences and Humanities Research Council.

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