Stone Age Ecology

Introduction

Biomass is the mass of living biological organisms in a given area or ecosystem at a given time[1]. The symbiosis between hunter-gatherers and ecosystem can be seen as two processes. The African ecosystem produced Homo Sapiens and continues to generate humans through food production, this you can call **generative symbiosis**. The process in the other direction, actively exploring and using the ecosystem's food resources, we can then call **active symbiosis**. That way, you get a cycle. In that cycle, human language ability developed thousands of years ago. A hypothesis that can be added to that is the development of egalitarianism, this was common among Homo Sapiens living at the time until 10,000 years ago.

Primary Biomass supplied by the Ecosystem

Biomass in nature is the material biological result of photosynthesis by producers. This biological production varies greatly among ecosystems, communities of life and biomes. The producers on land are mainly land plants (Embryophyta), in the oceans they are mainly algae. The total global living biomass is estimated at 550 billion tonnes of carbon, most of which is in forests.

Terrestrial biomass generally decreases markedly at each higher trophic level (plants, herbivores, carnivores). Examples of terrestrial producers are grasses, trees and shrubs. These have a much higher biomass than the animals that consume them, such as deer, zebras and insects. The level with the least biomass are the highest predators in the food chain, such as foxes and eagles.

In a temperate grassland, grasses and other plants are the primary producers at the bottom of the pyramid. Then come the primary consumers, such as grasshoppers, voles and bison, followed by the secondary consumers, shrews, hawks and small cats. Finally the tertiary consumers, large cats and wolves. The biomass pyramid decreases markedly at each higher level.

Research by anthropologists and ecologists summarised by Marlowe shows that originally wild nature produced as much primary biomass as the first farmers did per square kilometre. Meanwhile, the industrialisation of agriculture with machines has increased agricultural productivity, even though this often comes at an environmental cost: groundwater is polluted; water shortages are imminent; moddder avalanches occur during heavy rainfall on slopes where trees have been cut down and so on. But 10,000 years ago, this was not a problem and so productivity was much lower. So switching to agriculture was not really a solution then. Mind you, late Pleistocene foragers then, even in rich habitats, probably needed very large home ranges of **about 175 km2 to survive**.

1 IUPAC, Compendium of Chemical Terminology, 2nd ed. (the "Gold Book") (1997). Online corrected version: (2006–) "biomass". doi:10.1351/goldbook.B00660,<https://goldbook.iupac.org/terms/view/B00660.html>.

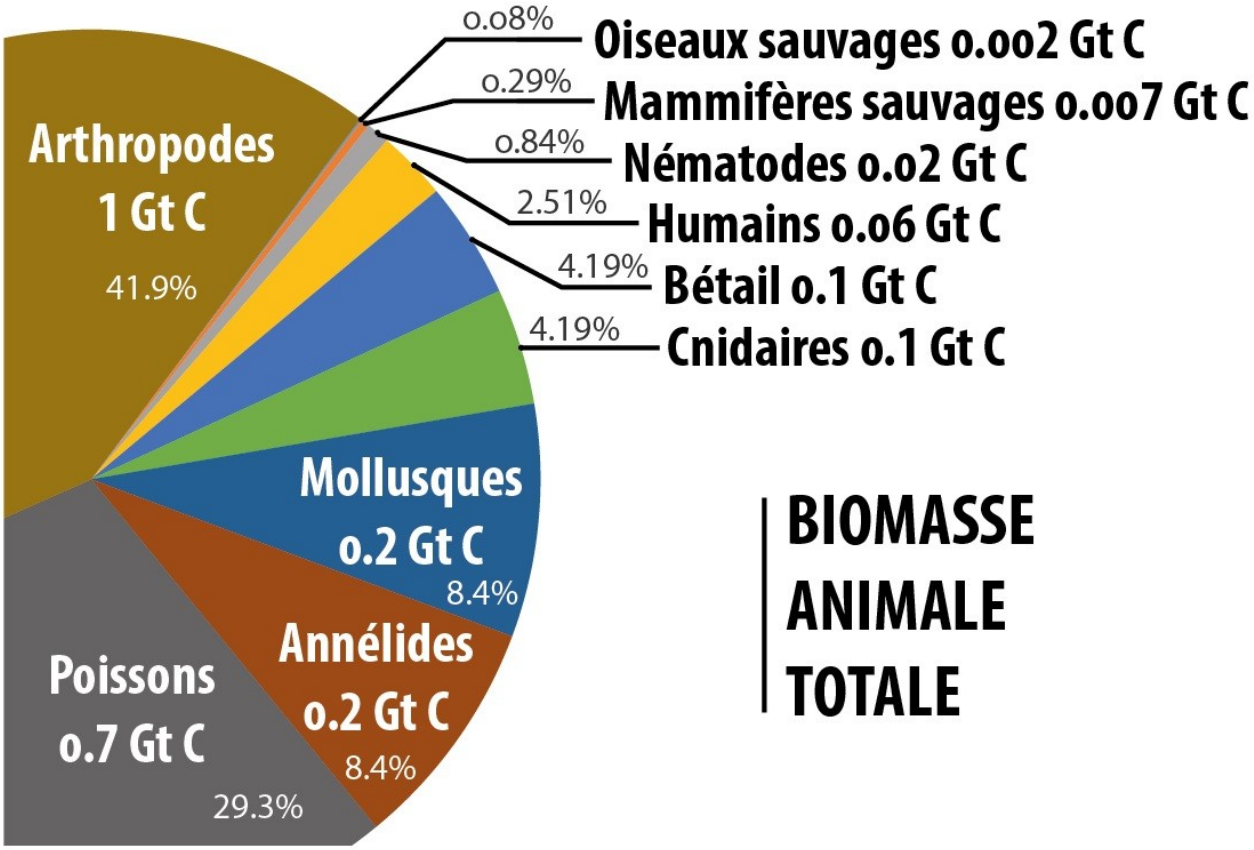

Figure 1: Total Biomass of animals on Earth, Courtesy Wikipedia

Genesis of language facility and egalitarianism

Remarkably, sexual selection was suggested as a basis for language development as early as 1995 by Chris Knight, Camilla Power and Ian Watts[2] which was reiterated in 2009 by Camilla Powers[3]. Meanwhile, it has been shown that sexual selection indeed played a role in the phylogenesis of Homo Sapiens through the spreading of the BAZ1B gene. Their argument was of course incomplete at the time, but based on the anthropological and archaeological research known at the time.

> "The argument in a nutshell is that language cannot evolve without cooperation between strangers; the only medium for securing such cooperation within and between groups is costly ritual (cf. Durkheim 1947 [1915]; Knight et al. 1995; Irons 2001; Sosis 2003)."[4]

It is striking how often rituals are referred to in anthropological literature of the 20th century even when it is about perfectly explicable acts. Cedric Broeckx does not deny the role of rituals but he says their significance was not the same for Neanderthals as for Homo Sapiens:

> “For me, self-domestication, by reducing levels of reactive aggression, that is, lowering levels of fear, and boosting levels of trust, created just the right context for symbolic

2 Knight, Chris, Camilla Power & Ian Watts, 1995,The Human Symbolic Revolution: A Darwinian Account, Cambridge Archaeological Journal 5:1 (1995), pp. 75-114, <http://dx.doi.org/10.1017/S0959774300001190>.

3 Power, Camilla, 2009, Sexual Selection Models for the Emergence of Symbolic Communication: Why They Should Be Reversed, In The Cradle of Language: Studies in the Evolution of Language, edited by Rudolf Botha and Chris Knight, 257–80,Oxford:OxfordUniversity Press, <https://academic.oup.com/book/48534/chapter-abstract/422386961?redirectedFrom=fulltext&login=false>.

4 Power, Camilla, 2009.

> communication to be stable (in an ever-expanding community, which is another consequence of trust). It made it possible for words to be detached from the bounds of reality (truth, reference), thereby allowing for human language to achieve a level of flexibility and creativity (world-making) that makes our system of communication and thought quite special. In other words, self-domestication created an ecology that made it possible for users (learners, communicators) to abandon the need to rely on "credible signaling" (an important function of past communicative systems, Mehr et al., 2021), in effect allowing them to suspend their disbelief in the face of "honest fakes," and setting the stage for the strongest meaning of "arbitrary" signals in the sense of Planer and Kalkman (2020) (see also Gasparri et al., 2022; Watson et al., 2022)."[5]

He also wants to stress the importance of the variation in our genome as a consequence of self-domestication:

> "I'd like to put forward the hypothesis that the variation in our genome briefly reviewed in this section contributed to shifting the balance between these two engines and promoted a "personality" type favoring innovation/exploration over imitation/exploitation. These are of course continuous dimensions, and we should not expect binary types here. Instead, we can think of them as two factors constituting the two principal components of a complex, multi-dimensional space."[6]

And:

> "My suggestion is very much in line with proponents of the "Cultural Intelligence" hypothesis, which claims that more frequent opportunities for social learning should boost an individual's repertoire of learned skills (Van Schaik and Burkart, 2011; Forss et al., 2016; Schuppli et al., 2017; Forss and Willems, 2022). Put differently, improved social learning should boost asocial learning (and in general, a reciprocal causality pattern between biology and culture, with each imposing selective forces on the other, Whitehead et al., 2019)."

Developmental psychologist Michael Tomasello suggests that shared intentionality in pursuing a common goal is the hallmark of human interaction as opposed to that of other apes. The gesture of pointing, for example, requires a mutual understanding of the pointer's intention to share information. In support of this, the "cooperative-eye hypothesis" assumes the corollary that only the genus Homo has a specific physiology - eyes that are almond-shaped with white sclera - that makes it easy to see others' points of interest and suggests that this evolved to facilitate communication and cooperation[7] [8].

Monkeys do not point, nor do they seem to be able to interpret pointing, while human infants invariably seem to point before they speak. Although small children are sometimes called little monkeys, they have far more brains than monkeys. Experimental studies show that 12-month-old

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5 Cedric Boeckx, 2023, What made us "hunter-gatherers of words", Front. Neurosci., 09 February 2023, Sec. Neurogenomics, Volume 17 - 2023, https://doi.org/10.3389/fnins.2023.1080861, <https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2023.1080861/full>.

6 Cedric Boeckx, 2023.

7 Tomasello, Michael, Malinda Carpenter, 2006, Shared intentionality, First published: 20 December 2006, Developmental Science, <https://doi.org/10.1111/j.1467-7687.2007.00573.x>.

8 Tomasello, M.; Rakoczy, H., 2003, "What makes human cognition unique? From individual to shared to collective intentionality". Mind & Language, 2003; 18: 121–147.

infants' pointing is already a communicative act in which information is intentionally conveyed to share interest with or give information to others[9].

Our ancestral primates and also the Neanderthals already cooperated, but not on an egalitarian basis. Neanderthal society was structured in a hierarchical way. Inbreeding was legion[10]. Harris and Nielsen estimate that Neanderthals were on average at least 40% less 'fit' than modern humans due to inbreeding[11]. Though their had larger skulls, neurogenesis in frontal neocortex of Homo Sapiens resulted in more neurons than Neanderthal had in the frontal lobe of the brain[12].

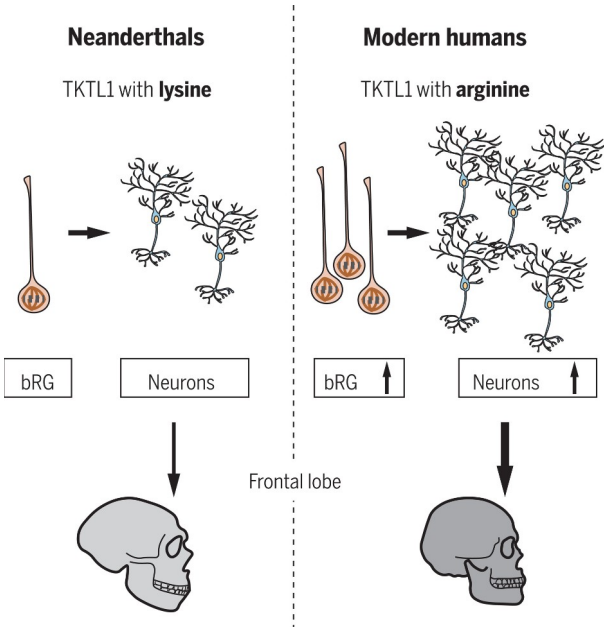

Figure 2: Antonio Rosas et al. 2017, TKTL1 and hominin cortical neurogenesis

Cooperation of Neanderthals was done in a hierarchical context such as in the military not the way the egalitarian hunter-gatherers acted.

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9 Liszkowki, Ulf, 2005, Human twelve-year-old point cooperatively to share interest with and provide information for a communicative partner, Max-Planck Institute for Evoltionary Antropology, Leipzig, <https://www.researchgate.net/publication/300854204_Human_twelve-month-olds_point_cooperatively_to_share_interest_with_and_helpfully_provide_information_for_a_communicative_partner>.

10 Vaesen K, Scherjon F, Hemerik L, Verpoorte A. Inbreeding, Allee effects and stochasticity might be sufficient to account for Neanderthal extinction. PLoS One. 2019 Nov 27;14(11):e0225117. doi: 10.1371/journal.pone.0225117. PMID: 31774843; PMCID: PMC6880983, <https://pmc.ncbi.nlm.nih.gov/articles/PMC6880983/>.

11 Harris K, Nielsen R, The genetic cost of Neanderthal introgression, Genetics 203(2):881–91 (2016). 10.1534/genetics.116.186890, <https://pmc.ncbi.nlm.nih.gov/articles/PMC4896200/>.

12 Pinson, Anneline, Lei Xing, Takashi Namba, Nereo Kalebic, Jula Peters, Christina Eugster Oegema, Sofia Traikov, Katrin Reppe, Stephan Riesenberg, Tomislav Maricic, Razvan Derihaci, Pauline Wimberger, Svante Pääbo, Wieland B Huttner: “Human TKTL1 implies greater neurogenesis in frontal neocortex of modern humans than Neandertals”, Science. 09. September 2022 doi: 10.1126/science.abl6422. <https://www.science.org/doi/10.1126/science.abl6422>.

Experiments with monkeys in captivity show that they also recognise injustice and protest against it[13]. Prior to the emergence of the socio-cognitive niche, a mutation of the human genome caused the inhibition of reactive aggression as demonstrated by recent palaeogenetic research[14]. Cedric Boeckx and many linguists with him situate the development of human language ability there[15]. Our hypothesis is that the evolution of linguistic ability also assumed equal and equal partners. Language is pre-eminently a **cooperative interactivity** as to Paul Grice.

All animals use forms of communication, from reptiles, birds to mammals. This has two main functions, warning of danger and inviting mating. Those messages are clear. When developing complex language, it was important not to lose that clarity. Because symbolic language also gives the opportunity to fake, to mislead. So the communicative intent had to be clear otherwise it could not be relied upon.

The need to exclude ambiguity in language development has previously been raised by the author in another context[16]. Language presupposes relatively high levels of mutual trust14[17]. Hierarchy would install distrust in that situation. That need for mutual trust was a necessity for survival. Thus, this necessity fostered egalitarianism. Boeckx quotes Thomas and Kirby:

> "Building on previous work (e.g., Kirby et al., 2015), Thomas and Kirby (2018) view the process of structure-creating cultural evolution as requiring two key precursor traits at the heart of which they place self-domestication: (i) the transmission of the communication system through learning; and (ii) the ability to infer the communicative intent associated with a signal or action."[18]

This gave rise to the emergence of social networks. Social networks exhibit striking structural regularities and both theory and practice suggest that networks facilitated the development of large-scale cooperation among humans. Coren Apicella, Frank W. Marlowe, James H. Fowler and Nicholas A. Christakis describe the social networks of the Hadza, a population of hunter-gatherers in Tanzania.

13 Brosnan, S. F. and F. B. De Waal ,2003, Monkeys reject unequal pay. Nature 425(6955): 297-299, <http://www.emory.edu/LIVING_LINKS/publications/articles/Brosnan_deWaal_2003.pdf>.

14 Matteo Zanella et al. , Dosage analysis of the 7q11.23 Williams region identifies BAZ1B as a major human gene patterning the modern human face and underlying self-domestication. Sci. Adv.5, eaaw7908 (2019). DOI:10.1126/sciadv.aaw7908. <https://www.science.org/doi/10.1126/sciadv.aaw7908>.

15 Cedric Boeckx, 2023.

16 Verhoeven, Daniel, 2006, Can we resolve ambiguity by email, academia.edu, <https://www.academia.edu/11150774/Can_we_resolve_Ambiguity_by_email>.

17 Knight, C. (2010). "The origins of symbolic culture," in Homo Novus-A Human Without Illusions (Berlin: Springer), 193–211.

18 Cedric Boeckx, 2023.

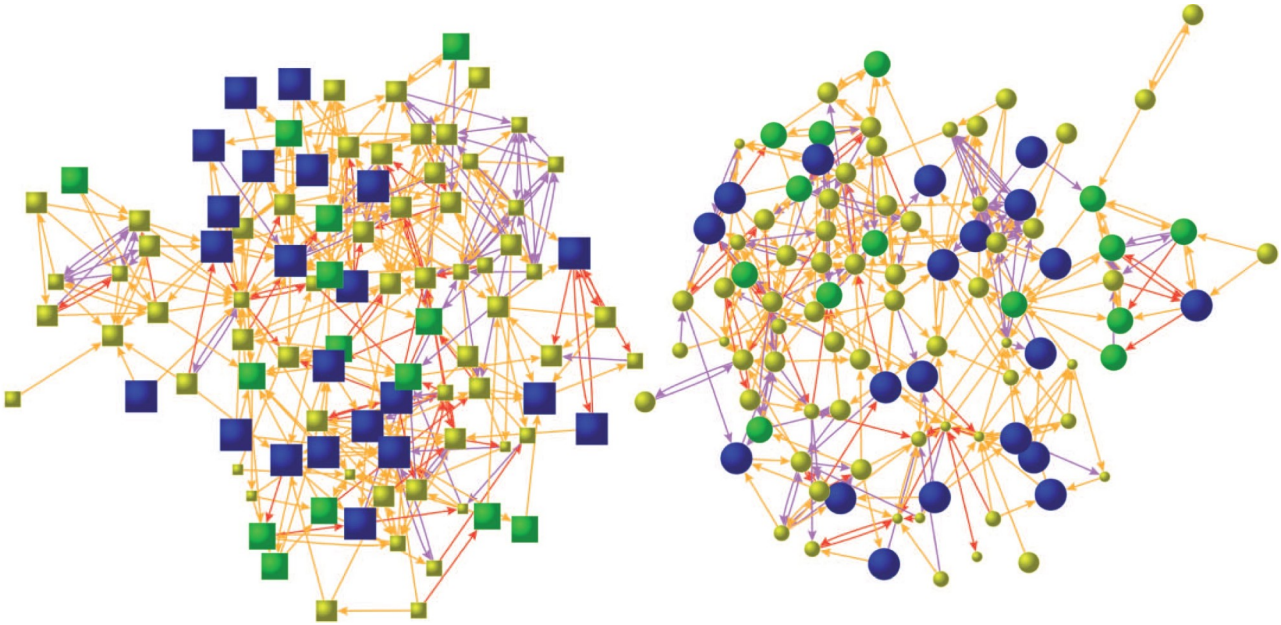

Figure 3: Structural features of modern social networks also exist in Hadza networks. a, Cumulative in-degree distributions show the fraction of the population that has at least k social ties. The distributions for the campmate and gift networks are significantly different from random networks with the same number of nodes and edges (Kolmogorov–Smirnov test, P,10215) and have fatter tails; the random distributions are shown separately for campmate and gift networks (in grey). The gift networks within each camp (ordered by size of camp from smallest, yellow, to largest, blue) show similar distributions of indegree. b, Estimates based on dyadic models of social ties (see Supplementary Information) show that a 1-s.d. change in similarity in characteristics between two people significantly increases the likelihood of a social tie (homophily), Macmillan Publishers Limited. All rights reserved, https://greatergood.berkeley.edu/images/uploads/Apicella-CooperationHunterGatherers.pdf

They show that Hadza networks have important properties that are also found in modern social networks,

> "including a skewed degree distribution, degree assortativity, transitivity, reciprocity, egographic decay and homophily."

Social distance is as important as genetic relatedness and physical proximity. This explains assortativeness in mutual cooperation[19]. The emergence of language facility and hence deliberative ability in a context of 'cooperation needed to provide food' was an indispensable and fertile causal link. In that cyclical social dynamic, egalitarianism could be stabilised. It is obvious that language development and the genesis of egalitarianism took place at the level of the forming ethno-linguistic tribe. Equality will be further developed and stabilised in the activity groups at the level of the 'fused band '. Co-operation provided continuity.

A New Social Cognitive Niche

Andrew Whiten & David Erdal propose that a ‘cognitive niche’ reliant on intelligence and technology is compelling, yet insufficient. They present evidence from a diversity of sources

19 Apicella, Coren L., Frank W. Marlowe, James H. Fowler, & Nicholas A. Christakis. ,2012, Social networks and cooperation in hunter-gatherers, Nature, Vol. 481, 26 January 2012, doi:10.1038/nature10736, <https://greatergood.berkeley.edu/images/uploads/Apicella-CooperationHunterGatherers.pdf>.

supporting the hypothesis of in the evolution of a new socio-cognitive niche, the principal components of which include **forms of cooperation, egalitarianism, mindreading (also known as 'theory of mind'), language and cultural transmission**, that go far beyond the most comparable phenomena in other primates[20]. They explain the interactions between these components:

> "Mindreading <---> Culture. Mindreading facilitates cultural transmission through the recognition of knowledge, ignorance, intentions and other mental states of others, underwriting teaching. In turn, culture supports mindreading through a publicly shared mentalistic framework, which also links with language in that it is explicitly expressed through a lexicon including such concepts as 'desires', 'thoughts' and 'beliefs'."
>
> "Language <---> Culture. Culture supports language through the whole process of language acquisition. In turn, language carries large swathes of cultural transmission, from instruction to story-telling."
>
> "Mindreading <---> Language. Mindreading has been argued to underwrite the intentionality of human language, in which utterances are delivered with the intent that others will take certain meanings from them. In turn, terminology and talk about what is in or on our minds is embodied in language."
>
> "Cooperation <---> Egalitarianism. Cooperation and egalitarianism reinforce each other because foragers are more likely to be prepared to cooperate in the quest for resources if they will receive a reasonable share of them. This linkage is so tight that in the following, for economy, we refer to this sub-complex as 'cooperative-egalitarianism'."
>
> "Cooperative-egalitarianism <---> Culture. Cooperation and egalitarianism support the free sharing of information that supports cultural transmission, the sharing of innovations and thus cultural evolution. In turn, culture provides techniques (such as those of hunting weaponry) that support forms of cooperation, and an explicitly stated ideology of generalized altruism that supports egalitarianism."
>
> "Cooperative-egalitarianism <---> Language. Language facilitates interpersonal coordination such as planned foraging expeditions, and reciprocal agreements such as marriage."
>
> "Cooperative-egalitarianism <---> Mindreading. Mindreading facilitates interpersonal coordination, empathy and a shared sense of fairness. In turn, the cooperative and egalitarian ethos of human hunter–gatherers means that there are positive reasons for offering one's states of mind to be read by others, rather than keeping them opaque."
>
> "These inferences about positive feedback loops are here outlined at the level of short- to medium-term causality: that is to say, each of these aspects of social cognition appears to operate to support others in the day-to-day life of hunter–gatherers."[21]

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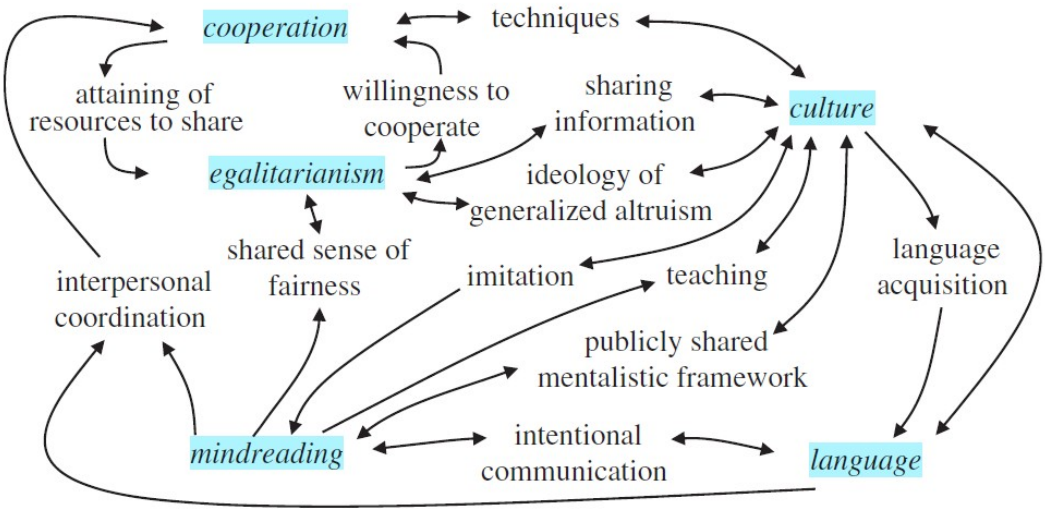
20 Whiten, Andrew, and David Erdal. 2012. "The Human Socio-cognitive Niche and Its Evolutionary Origins." Philosophical Transactions of the Royal Society B 367: 2119–29, <https://www.researchgate.net/publication/228067277_The_Human_Socio-Cognitive_Niche_and_Its_Evolutionary_Origins>.

21 Whiten, Andrew, and David Erdal. 2012.

They summarise their findings in the info-graph below. See following chapters for more on this.



Afbeelding 4: Principal classes of social cognition (in italic) in hunter–gatherer bands and inferred reinforcing relationships between them.

Diet and life expectancy of hunter-gatherers

Early studies of hunter-gatherer diets by archaeologists and nutritionists may have overestimated meat consumption. Researchers claimed that 73% of global hunter-gatherers got 56% to 65% of their energy from animal foods17[22]. This miscalculation is due to the fact that archaeologists can easily reconstruct the animal diet when they excavate bones. But plant digestion, of course, leaves no trace.

To find out that suspicion, Jennifer C. Chen, Mark S. Aldenderfer,Jelmer W. Eerkens,BrieAnna S. Langlie,Carlos Viviano Llave, James T. Watson and Randall Haas, used stable isotope chemistry of human bones from 24 individuals from the early Holocene sites Wilamaya Patjxa (9.0-8.7 cal. ka) and Soro Mik'aya Patjxa (8.0-6.5 cal. ka), located at 3800 metres above sea level on the Andean Altiplano in Peru.

Contrary to expectations, Bayesian mixture models based on isotope chemistry showed that plants dominated the diet and accounted for 70-95% of the average diet. Paleo-ethnobotanical data further show that tubers may have been the main source of sustenance. These findings update our understanding of the earliest foraging economies and the path to agricultural economies in the Andean highlands. The findings further suggest that the first subsistence economies of early human populations that adapted to new landscapes may have been more plant-based than current models suggest18[23].

22 Cordain, Loren, Janette Brand Miller, S Boyd Eaton, Neil Mann, Susanne HA Holt, John D Speth, Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets12, The American Journal of Clinical Nutrition, Volume 71, Issue 3, 2000, Pages 682-692, ISSN 0002-9165, https://doi.org/10.1093/ajcn/71.3.682. <https://www.sciencedirect.com/science/article/pii/S0002916523070582>.

23 Chen, Jennifer C., Mark S. Aldenderfer,Jelmer W. Eerkens,BrieAnna S. Langlie,Carlos Viviano Chen JC, Aldenderfer MS, Eerkens JW, Langlie BS, Viviano Llave C, Watson JT, et al. (2024) Stable isotope chemistry reveals plant-dominant diet among early foragers on the Andean Altiplano, 9.0–6.5 cal. ka. PLoS ONE 19(1):

Hunter-gatherers were omnivorous. They ate a mix of raw and cooked food. They ate a larger portion of the animal than contemporary humans, consuming marrow, organs, fat, roe and other parts. Such use of the animal meant that they did not consume the relative amount of lean muscle meat that contemporary people do. Modern practices in urbanised areas focus on consuming what is essentially the least nutritious part of the animal. The full utilisation of the animal by hunter-gatherers also meant that they received a higher proportion of lipids in the diet than many contemporary humans.

They ate a large number of plant species and included a wide variety of species in their diet. In temperate regions, for example, more than 100 species were eaten throughout the year (this figure is much higher in subtropical and tropical regions). The exact species depended on location (a function of many attributes, including latitude, altitude, proximity to large bodies of water). These included fleshy fruits, seeds, tubers, greens/shoots, cereals, nuts and flowers. No highly modified species were consumed by hunter-gatherers (i.e. the plants were wild forms; seedless, sugar-rich, fibre-poor plants were not used in the diet).

Figure 5: The Yanomami people use ~500 plant species daily for food, clothing, housing and much more. Photo © Fiona Watson/Survival International.

They used relatively simple means to refine food, including (but not limited to) grinding, drying, cooking and soaking. They did not produce highly refined foods in which certain microscopic components were removed. For example, they did grind nuts and grains to make flour, but they did

e0296420. https://doi.org/10.1371/journal.pone.0296420 <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0296420>.

not remove the bran before grinding (a method that produces white flour). As such (and along with other details of their diet), no artificial ingredients or nutritional supplements were needed.

Given the absence of deformities (e.g. narrow faces, crowded and/or crooked teeth, impacted wisdom teeth, deformed teeth), the low incidence of dental caries and the virtual absence of chronic diseases that plague people in urbanised countries, they serve as role models for health. Various observations show an average food intake per day of 2130 to 2160 calories19[24]. This is within the standard recommended by the WHO, 2000 to 2500 calories[25].

Life expectancy among hunter-gatherers requires a separate statistic because of the high infant mortality rate in the absence of modern medical care, 20% to 40%. For example, the Tsimané, an indigenous food-seeking people in lowland Bolivia have a modal lifespan of 70 years[26]. Gurven and Kaplan suggest at a life expectancy of 68 to 78 years[27].

24 Sahlins, Marshall, 2016, Stone Age Economics, ark:/13960/t35190x6x, Internet Archive HTML5 Uploader 1.6.3, <https://archive.org/details/StoneAgeEconomics_201611/mode/2up>, pp. 17-31.

25 WHO,2020, Healthy Diet, <https://www.who.int/news-room/fact-sheets/detail/healthy-diet>.

26 Kaplan, Hillard et al., 2017, Coronary atherosclerosis in indigenous South American Tsimane: a cross-sectional cohort study, The Lancet, Volume 389, Issue 10080, 1730 – 1739 <https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)30752-3/abstract>.

27 Gurven, M., & Kaplan, H. (2007). Longevity among hunter-gatherers: A cross-cultural examination. Population and Development Review, 33(2), 321–365. <https://onlinelibrary.wiley.com/doi/10.1111/j.1728-4457.2007.00171.x>.