MITTEILUNGEN
DER
ANTHROPOLOGISCHEN GESELLSCHAFT IN WIEN

CXLVII. BAND

Herausgegeben von der

ANTHROPOLOGISCHEN GESELLSCHAFT IN WIEN

Schriftleitung
KARINA GRÖMER

Redaktion
Ur- und Frühgeschichte
KARINA GRÖMER

Ethnologie
HERMANN MÜCKLER

Anthropologie
HERBERT KRITSCHER

2017

VERLAG DER ANTHROPOLOGISCHEN GESELLSCHAFT IN WIEN
WIEN

Anthropologische
Gesellschaft in Wien

Mitgliedsbeitrag für Mitglieder in Österreich € 30,- (Studenten bis 27 Jahre € 10,-) ohne Bezug der „Mitteilungen". Für Mitglieder im Ausland € 50,- mit Bezug der „Mitteilungen". Zahlungen auf das Konto der Bank Austria IBAN: AT79 1100 0094 3411 8700; BIC: BKAUATWW.

Die „Mitteilungen der Anthropologischen Gesellschaft in Wien" erscheinen einmal jährlich.

Die Lieferung erfolgt auf Gefahr des Empfängers. Kostenlose Nachlieferung in Verlust geratener Hefte erfolgt nicht.

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Redaktionsschluss ist jeweils der 30. Juni. Erscheinungstermin: Dezember desselben Jahres.

Die Autoren werden um Beachtung der „Richtlinien für die Abfassung von Manuskripten für die MAGW" ersucht (zuletzt abgedruckt in MAGW 132 sowie auf der Homepage)

Die „Mitteilungen der Anthropologischen Gesellschaft in Wien" sind das Organ der Disziplinen, die anthropologische Forschung auf einzelwissenschaftlicher Grundlage betreiben, in erster Linie der physischen Anthropologie, Ethnologie, Ur- und Frühgeschichte sowie Volkskunde. Demgemäß wird grundsätzlich der anthropologische Aspekt in seinem synthetischen Charakter wahrgenommen. Die Zeitschrift verfolgt nicht die Zwecke der Spezialforschung auf Einzelgebieten (Statistiken, Reiseberichten, Materialvorlagen, Fundberichten usw.), die Beiträge sollen vielmehr den gemeinsamen Grundlagen und Zielen der in der Gesellschaft vertretenen Wissenschaften gewidmet sein.

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Umschlagbild: Lebensbild zum Kochen im Hallstätter Salzbergwerk um 600 v. Chr.
(aus Beitrag Kern, Abb. 7).

Homepage der Anthropologischen Gesellschaft in Wien: www.ag-wien.org

Eigentümer und Herausgeber: Anthropologische Gesellschaft in Wien, A-1010 Wien, Burgring 7
VERLAG DER ANTHROPOLOGISCHEN GESELLSCHAFT IN WIEN

Herstellung: agensketterl Druckerei GmbH, A-2540 Bad Vöslau

ISSN 0373-5656

Zu diesem Band

„Ernährung und Esskultur“

Es gibt kaum einen Bereich der menschlichen Betätigung, der so substanziell ist und dem man sich so wenig entziehen kann wie jener der Ernährung. Die halbjährlich in Lifestylemagazinen Europas propagierten Erkenntnisse zur Ernährung, zu Diättips, aber auch zu den neuesten Foodtrends zeigen deutlich die Brisanz des Themas. Bei der medialen Ausschlachtung dieser Themenbereiche (vor allem bei Diäten und „bewusster Ernährung“) wird oft auf vermeintliche Fakten aus Geschichte und Völkerkunde zurückgegriffen (z. B. die sogenannte „Paleodiät“).

Beim vorliegenden Band sollen nun unterschiedlichste Aspekte rund um das Thema Ernährung und Nahrungsgewohnheiten miteinander verbunden werden, gemäß dem interdisziplinären Ansatz der die seit fast 150 Jahren bestehende Anthropologische Gesellschaft, die Biologische Anthropologie, Archäologie, Volkskunde und Ethnologie (Kultur- und Sozialanthropologie) miteinander vernetzt.

Wichtige einführende Beiträge finden sich in den Kapiteln zur Anthropologie, wo auf den generellen medizinisch-ernährungsphysiologischen Aspekt eingegangen wird, sowie bei der Völkerkunde, wo Nahrung als sozio-biokulturelles Phänomen theoretisch diskutiert wird. Vor allem die Beiträge aus Archäologie und Völkerkunde beschäftigen sich in weitem zeitlichen Bogen von der Steinzeit weg mit Beispielen aus der ganzen Welt und der Frage, welche Ressourcen in bestimmten Zeitabschnitten und Regionen zum Zweck der Nahrungsgewinnung ausgebeutet wurden. Thematisiert werden auch die verschiedenen Möglichkeiten der wissenschaftlichen Forschung wie Archäobotanik, Archäozoologie oder völkerkundliche Feldforschung.

Anschließend wird der Frage nachgegangen, wie sich Nahrungsmittelproduktion und Nahrungszubereitung gestalten. Kochgeräte, Geschirr, Werkzeug und Serviergefäße finden sich im archäologischen Fundgut ebenso wie bei ethnographischen Beispielen. Aus den rezenten Beobachtungen, die Hilfsmittel für das Kochen, Braten und Backen betreffen, können Rückschlüsse auf die Vorzeit gezogen werden. Getränke sind wie feste Nahrung für den menschlichen Körper unbedingt notwendig – in diesem Band wird auf die Geschichte des Bieres und auf seine Bedeutung eingegangen.

Besondere Aspekte, wie Nahrungstabus, die freiwillige Beschränkung bei der Nahrungsaufnahme auf ausschließlich pflanzliche Stoffe oder auf koschere Produkte runden das Bild bezüglich Ernährung ab. Ebenso thematisiert werden weiters die Probleme bei unsachgemäßem Umgang mit Nahrung, die sich dann in krankhaften Erscheinungen wie Übergewicht oder auch Vergiftungen äußern können.

Ein herzlicher Dank sei hier auch an Frau Dr. Walpurga Antl-Weiser ausgesprochen, die die Korrekturen der englischen Texte durchführte. Eine wertvolle Hilfe im Lektorat stellen Herr Dipl.-HTL-Ing. Eduard Wexberg und Frau Mag. Inge Schierer dar, die sorgfältig alle Beiträge auf Fehler prüfen.

Die Schriftleitung
Karina Grömer

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Mitteilungen der Anthropologischen Gesellschaft in Wien (MAGW)
Band 147, 2017, S. 13–30

Breast is best – and are there alternatives?
Feeding babies and young children in prehistoric Europe

von

Katharina Rebay-Salisbury, Vienna

Zusammenfassung

Als Säugetiere sind auch menschliche Mütter biologisch hervorragend daran angepasst, ihre eigenen Nachkommen nach der Geburt zu stillen, um sowohl eine optimale Ernährung als auch eine gute Mutter-Kind-Beziehung zu gewährleisten. In menschlichen Gesellschaften gibt es jedoch eine beträchtliche Vielfalt in der Praxis und Dauer des Stillens sowie der damit verbundenen Einstellungen und Überzeugungen. Frauen in Jäger- und Sammlergesellschaften stillen normalerweise mehrere Jahre lang, während der sesshafte Lebensstil von Ackerbauern häufig zu einer Verkürzung der Stilldauer führt. Stressmarker im menschlichen Skelett, Isotopensignaturen in Knochen und Zähnen sowie Mikroabrasionsspuren von Milchzähnen können uns über die Ernährung im Kleinkindalter und über das Abstillalter in archäologischen Kontexten informieren. Zu den Alternativen zum Stillen durch die eigene Mutter zählen Stillen durch Angehörige oder Ammen sowie das Füttern von Tiermilch und Getreideprodukten. Sauggefäße könnten solche Praktiken für die Urgeschichte belegen.

Summary

As mammals, human mothers are biologically well adapted to breastfeed their own offspring after birth, ensuring optimal nutrition and bonding between mother and child. In human societies, however, there is considerable variation in the practice and duration of breastfeeding, as well as associated beliefs. Hunter-gatherers typically breastfeed for several years, whereas the adoption of a sedentary lifestyle in farming communities frequently led to a shortening of the breastfeeding period. Stress markers in the human skeleton, dental micro-wear, and isotopic signatures in bones and teeth can inform us about dietary changes and the age of weaning in infancy. Alternatives to breastfeeding include cross-nursing and wet-nursing, and feeding with animal milk or grain-based alternatives. Feeding vessels of the late Bronze and early Iron Ages may be evidence of such practices.

Introduction

Breastfeeding is an integral component of infant care of all human societies, and an important part of the mother-infant relationship. As mammals, human mothers are optimally biologically adapted to feed their offspring and babies are optimally adapted to receive nutrition this way. Breastfeeding is, however, also a cultural practice. For many women and babies, breastfeeding does not come naturally and has to be learnt, by observation, instruction, trial and error and practice. Advice on breastfeeding is probably harder to find today than it was in the past. Despite of the abundance of information on the internet, women currently have very few babies and breastfeeding mothers are often excluded from view and participation in social events.

In the course of the ERC Starting Grant 2015 project “The Value of mothers to society” we are investigating infant feeding practices, as they are an important component of mothering as a cultural practice. This article discusses isotopic analyses that have been used to study breastfeeding duration and the age of weaning, and recent critiques. It also explores alternatives to breastfeeding, which must have existed in case the mother died or lactation did not work as expected.

Breastfeeding variability

In contemporary societies, breastfeeding rates are highly variable, particularly in the western world, which demonstrates that even culturally similar groups may have very different feeding strategies. Scandinavian countries have the highest breastfeeding rates in recent years (surveys were taken 1994/95), with 98% of women breastfeeding at birth and 80% continuing to do so after three months in Norway. In Germany, 96% of all women initiate breastfeeding at birth and 83% were still breast feeding three months later, whereas in France, only 67% of all women started to breastfeed after birth and 34% were still breast feeding at three months. Only 62% of women initiated breastfeeding in England and Wales, 48% in Scotland, and 41% in Northern Ireland, and 27% of babies in the United Kingdom still breastfed at four months (Fairbank et al. 2000, 2; Walburg et al. 2010). In the United States, breastfeeding rates in 2002 were 71% at birth and 44% at six months, compared to 81% and 52% in 2013 (Centers for Disease Control and Prevention 2016); in all countries, breastfeeding is gaining popularity as its heath benefits become more widely known and public health interventions are showing positive effects.

Two primary factors influence the uptake and duration of breastfeeding: first, beliefs and attitudes about the female body – in cultures in which breasts are primarily associated with sex rather than feeding babies, it is hard to breastfeed in public, and societal attitudes to breastfeeding in public are directly linked to breastfeeding duration (Scott et al. 2015). Establishing separate, secluded places for breastfeeding mothers, such as the Nursing Pods at Newark Airport (Rebay-Salisbury 2016), only address part of the problem: rather than normalising the view of breastfeeding mothers in public places, they continue their social exclusion. Second, the separation of working mothers from their babies in the first year of their lives limits breastfeeding – although breast pumps may provide a solution for short periods of separation, breastfeeding is only practical for young infants when mother and baby are together almost all the time. Breastfeeding rates are thus connected to social welfare systems that provide paid maternity leave (cf. Hawkins – Griffiths – Dezateux 2007; Ogbuanu et al. 2011). Although breastfeeding benefits both mothers and babies, it is no longer a factor in infant survival for modern societies. In the past, however, it was a crucial survival strategy.

Breast milk composition and benefits

Breast milk is a complex and dynamic mixture; during the first six months of life, no additional fluid or nutrient is required for a healthy infant. It is hard to measure the composition of breast milk, because the production of breast milk is perfectly adapted to the babies needs as they grow, and thus varies with stage of lactation after birth and between individuals (Robinson 2015). In the first three to five days after birth, the mother produces colostrum, a milk that is low in fat, high in carbohydrate, protein and antibodies. It is easily digested and has a laxative effect to help the infant excrete bilirubin, which helps to prevent jaundice. Transitional milk is produced until the end of the second week, before mature milk follows. Mature human milk contains about 3–5% fat, 0.8–0.9% protein, 6.9–7.2% carbohydrate calculated as lactose and 0.2% mineral constituents, the rest is water. Its energy content is 60–75 kcal/100 ml (Jenness 1979). In addition to variation based on age, breast milk composition also varies during each feed: the baby receives diluted milk first to address thirst and fatty milk before the breast is empty to address hunger. The mother's nutritional status has the largest effect on breast milk composition, but her age and the number of children she has given birth to before also have an impact. Environmental factors such as heat, humidity and seasonality play a further role (Prentice 1996).

In addition to macro-nutrients and water, breast milk contains fatty acids, amino acids, minerals, vitamins and trace elements for a healthy tissue growth and development (Prentice 1996), as well as anti-microbial and anti-inflammatory factors, enzymes, hormones and growth factors. Through breast milk, the mother's and infant's immune system are linked, and the transmission of maternal antibodies plays a vital role in preventing the colonisation of pathogens in the gut. Breastfed babies have lower rates of gastrointestinal and respiratory infections. More and more benefits of breast milk components are discovered, e. g. the role of oligosaccharides for the development of a healthy microbiome or the role of fatty acids for brain development, which not only impact infant health, but have long lasting effects on the quality of life in the long term (Goldberg et al. 2010; Robinson 2015).

Most important, perhaps, is the contribution of breastfeeding to mother-child bonding. The demonstrated higher intelligence of breastfed infants seems to be due to this effect rather than the composition of human milk (Kosse 2016). Breastfeeding is positively correlated with parental investment, so much that weaning-age is sometimes used as a proxy to assess it (Humphrey 2010).

Breastfeeding further improves maternal health. The release of hormones such as prolactin and oxytocin contributes to psychological well-being and prevents post-partum depression. Physically, breastfeeding decreases postpartum bleeding, contracts the uterus after birth, reduces the risk of breast infections and over the long term, the rates of breast and ovarian cancers, as well as a range of diseases that do not, at first site, seem linked (Meek 2011).

The cost and evolution of breastfeeding

Breastfeeding is metabolically very costly for the mother; it requires up to 500 additional kcal per day. The negative energy balance in unrestricted breastfeeding may be one reason of why breastfeeding is effective in preventing conception; other explanations include that the constant suckling of infants at the breast keeps the mothers' levels of the hormone prolactin high, which suppresses ovulation (Thompson 2013). There is a clear relationship between the duration of breastfeeding and child spacing, even if the exact underlying mechanism remains insufficiently investigated.

The cost of the reproductive cycle for the mother comprises the costs of pregnancy, breastfeeding and carrying babies, of which lactation is the most demanding (Thompson 2013, 294). Producing breast milk and breastfeeding is a less efficient way of energy transmission compared to placental absorption. A growing baby requires more and more food, and its increasing weight also increases the mother's burden when carrying the infant. Interestingly, the high costs of breastfeeding are met primarily by increased energy intake and reduction of expenditure, and, although the mothers' body fat stores does buffer against nutritional stress and protect her own health, there is hardly any relationship between the mother's BMI and her milk yield (Prentice et al. 1986). Even extremely undernourished women can provide enough breast milk to feed their babies, e. g. women who gave birth in NAZI concentration camps in the last days before the liberation (Rhodes 2015).

Looking at the metabolic costs of pregnancy, breastfeeding and carrying babies from an evolutionary angle, it becomes clear that the costs of bringing up babies are distributed differently over the life-span across different species. Biruté Galdikas and James Wood (Galdikas – Wood 1990) found a birth spacing of 45 months in gorillas, 66 months in chimpanzees and 92 months in wild orangutans. Human hunter-gatherers, for example the Gainj of highland Papua New Guinea, have an average of 43 months between births. Taking the mean of four non sedentary populations, Renee Pennington (Pennington 2001) calculated 39 months for hunter-gatherers.

Three and a half to four years between births is normal for prehistoric people before the adoption of agriculture, animal husbandry and a sedentary lifestyle. Alexandra Greenwald and colleagues (Greenwald – Eerkens – Bartelink 2016) found "The average age at full completion of weaning is approximately 28 months, or 2.3 years" except for three outliers that fall within 3.5–4 years for Late Holocene hunter-foragers in California. Likewise, the weaning process appears to have been completed by age three for a pre-contact Caribbean hunter-forager population from Canímar Abajo, Cuba (Chinique de Armas et al. 2017). Results from a Middle Holocene (4300–3000 BP) community in California, are closer to the 3–4 year range, on average, and indicate that male children were breastfed longer than females (Eerkens – Bartelink 2013). Similarly variable results have been reported for hunter-fisher-forager populations in Siberia (Waters-Rist et al. 2011). Here, an early pre-agricultural Neolithic group had relatively long weaning periods and later weaning age compared to a later Neolithic population.

In nomadic hunter-forager societies, children under four are typically carried by their mothers on gathering trips or when the group moves, adding another significant factor in the mothers' energy expenditure. Among the !Kung of the Kalahari Desert (Lee 1972), babies are carried everywhere in a small pouch on the back of the mother for the first one or two years of life. Between ages two and four, children are carried on the shoulders by their mothers. From the third year onwards, children increasingly spend time separated from their mothers in the camp, looked after by others while the mother is out. Up to age six or seven, children are partly carried by their fathers and partly walk some of the way. If children are born in close succession, i. e. two years apart, a mother ends up carrying both children until the older one is mature enough to walk on his/her own. Close child spacing is recognised as giving the mother 'a permanent backache' (Lee 1972, 332), as well as increasing child mortality (Jones 1986).

After Neolithisation, the adoption of a sedentary lifestyle with a more steady supply of high-calorie foods, the birth rate increased and demographics changed. Better nutrition, including foods suitable for weaning, a shorter duration of breastfeeding and reduced female mobility led to a greater number of pregnancies and births, as well as shorter intervals between births. This 'baby boom', the Neolithic Demographic Transition (Bocquet-Appel 2008; Porčić – Blagojević – Stefanović 2016), resulted in a significant growth of the population. During prehistory, the population steadily increased, with some fluctuations due to factors such as climate change and disease, perhaps until landscapes reached their pre-industrial carrying capacity. Johannes Müller has recently argued that between 6500 and 1500 BC, the population in Europe grew from about 1 to 13 million people (Müller 2013, 9). Studying breastfeeding and its duration is thus important to reconstruct past population dynamics.

An ethnographic survey of 113 nonindustrial populations from 97 cultures (Sellen 2001) found that supplementation with liquids other than breast milk and solid foods before six months was common in most societies, and that children were typically breastfed to c. 30 months, in more than 60% of all surveyed cultures beyond 24 months.

Studying breastfeeding and weaning ages in past societies

Assigning any given society a particular weaning age is problematic for two reasons. First, breastfeeding and weaning behaviour is a composite of highly individualised sets of practices and relations, and second, weaning is a process, not a fixed point in time. The whole time period from introduction of solid foodstuff alongside breastfeeding to the complete cessation of breastfeeding may be described as weaning. Linda Reynard and Noreen Tuross defined four stages of infant feeding: first, exclusive breastfeeding (about the first six months), second, breast feeding plus complementary feeding (foods fed only to infants and toddlers, from about six to twelve months), third, breast feeding plus complementary foods and family foods (foods shared by other juveniles and adults, from about 12 months) and fourth, complete cessation of both breast feeding and complementary food consumption and exclusive family food consumption (Reynard – Tuross 2015, 618). Recent years have seen an increase in popularity of baby-led weaning (Brown – Lee 2011; Wright et al. 2011), which discourages the feeding of traditional weaning foods in pureed form, and emphasises the babies' desire to lean feeding themselves. In fact, as every mother knows, it is hard to discourage infants and small children from grabbing food from one's plate and requires separating them from family eating. The process of weaning may take several months or years, but may also occur abruptly. Especially abrupt weaning is stressful for the infant, both nutritionally and immunologically, and can result in a higher risk of death. The age of weaning is culturally contingent (Howcroft 2013) and depends on many factors such as maternal investment, environmental factors, seasonality and availability of alternative foods. If sufficient suitable weaning foods are available, e. g. animal milk and cereals, weaning can occur earlier.

In the human skeleton, the age of weaning can best be assessed by a combination of different bio-anthropological approaches such as studying enamel hypoplasias, Harris lines, isotope ratios and dental micro-wear.

Disruptions in the formation of enamel are sometimes visible as hypoplastic lines at the outer tooth surface. These enamel hypoplasias indicate stress in early childhood, and may be connected to dietary changes and diseases (Hillson 2005; Martin – Harrod – Pérez 2013, 160; White – Black – Folkens 2012, 455). Since enamel formation follows a specific timeline, the location of hypoplasias on the teeth can be used to determine when, during foetal and childhood development, the stress period occurred (Grupe – Harbeck – McGlynn 2015, 351; Reid – Dean 2006). Peaks in the frequency of enamel hypoplasias may coincide with weaning, but they are general stress markers and may also point to generalised stress and exposure to environmental pathogens or growth disturbances of the teeth (Schurr 1997, 919).

Likewise, Harris lines are an unreliable marker of weaning. The lines of increased bone density in the trabecular bone in long bones indicate a temporary slow-down or arrest of bone growth due to malnutrition, disease or trauma, including mental stress (Grupe – Harbeck – McGlynn 2015, 349; Roberts – Manchester 2005, 240; White – Black – Folkens 2012, 430). Like enamel hypoplasias, they can be related to the individual's age at which the stress period occurred (Maat 1984). Conversely, Harris lines have been suggested to result from normal variation in growth (Papageorgopoulou et al. 2011).

Rather than indicating general periods of stress, isotope ratios of nitrogen and oxygen, as well as strontium and calcium in bones and teeth enlighten more specifically the way babies and small children were nourished, as the isotope signature of imbibed water and breast milk, as well as ingested food, is built into body tissues. The age of weaning can thus be traced through isotope ratios in children's skeletons and adult teeth (e.g. Bourbou et al. 2013; Howcroft 2013; Jay et al. 2008).

Infants who are breast-fed exclusively appear enriched in $\delta^{15}N$ (nitrogen): this trophic level effect results from their position in the food chain above their mothers. Nitrogen reflects the amount of animal protein in the diet, including milk (Eriksson 2013). $\delta^{15}N$ increases from diet to bone collagen by +3–4‰ with each trophic level. Whereas the body tissue of a newborn is thought to have similar values to his or her mother, the baby consumes the mother's tissue when breastfeeding begins, and rises to a higher trophic level, raising nitrogen levels by 2–3%. In theory, the differences between maternal and infant nitrogen isotope levels should be able to tell us whether a baby was breastfed or not (Beaumont et al. 2015). Animal milk is likely to depress $\delta^{15}N$, as it comes from herbivores that have lower trophic levels than humans. The introduction of cereals further depresses nitrogen values, as grain is high in carbohydrates, but has no nitrogen; this may be traced through carbon isotopes (Howcroft – Eriksson – Lidén 2012).

Oxygen isotope ratios ($\delta^{18}O$) are usually employed in palaeoecological studies, but they can also be used to trace water supply and differentiate breast milk from drinking water intake (Herring – Saunders – Katzenberg 1998). Breast milk, formed from body water, 'will be isotopically enriched in the heavier isotope (^{18}O) compared to the water she ingests, inducing elevated $\delta^{18}O$ values in infant tissues' (Britton et al. 2015, 227). Bone phosphate samples from medieval Wharram Percy, United Kingdom, were enriched in neonates/infants and closer to adult values from the age of 2–3 years. The general population pattern is similar to results obtained from $\delta^{15}N$ analysis of bone collagen, although differences at the individual level remain (Britton et al. 2015).

In archaeological case studies, isotope ratios are measured in skeletal and dental samples and related to the age of death of the sampled individual. The analysis of bone collagen from rib samples provide insights into the individuals' diet shortly before death, as bone undergoes constant turnover, and has been used to determine if infants were fed age-appropriate food in the weeks before death (e.g. Prowse et al. 2008; Schroeder et al. 2009). Samples from dentin, which does not remodel in the same way as bone and therefore reflects the diet at the time of tooth development, provides fine-grained insights into the age of weaning of individuals who survived the process. Gathering data at multiple points in time in relation to the growth of the individual is an invasive and costly technique, but gains valuable insight into weaning practices on a population level (e.g. Grupe – Harbeck – McGlynn 2015, 440–443; Howcroft 2013).

Recent critiques of using isotope studies to investigate breastfeeding patterns from skeletal and dental samples have brought up a number of points (Beaumont et al. 2015; Reynard – Tuross 2015). A central point of critique is the death bias. It is problematic to use samples from dead babies and children to reconstruct the living population; they have died from a specific cause and their diet may not be representative of the general population.

Approaches that match isotope values to age at death in infants are limited by two factors: understanding bone turnover, and precise estimation of age at death (Schurr 1997, 925). Bone turnover rates are estimated at 5–25% per year for adults (Martin – Burr – Sharkey 1998, 79–125), but vary within the skeleton. For infants, it has been estimated that it takes 31 weeks – more than half a year – to fully reflect dietary $\delta^{15}N$ signals after birth (Tsutaya – Yoneda 2013). It is unclear how long it takes for the diet to be represented in the infants' bones. Newborns and babies that died weeks after birth cannot have a breastfeeding-signal in their bones, but rather, represent the diet of their mothers. It has not been ascertained that mothers and babies have the same $\delta^{15}N$ levels in their bones at birth, as studies of modern people have focussed on hair and fingernail tissues. In archaeological samples, it is often difficult to match mother-infant pairs, so infants are often compared to the adult mean, which does not account for individual variability. A recent analysis of the burial of a Bronze Age mother with baby from Los Tolmos, Spain (Esparza et al. 2017, 231), has revealed a slight positive shift in $\delta^{13}C$ and $\delta^{15}N$ values in the infant, most likely because the mother's values reflect several years of diet before death, whereas her baby's reflect the diet of the mother's last months of life.

Fig. 1. Example of micro-wear on a 180 x 240µm section of the Facet 9 of an upper left second deciduous molar of an 11-year-old, showing parallel features indicative of tough or soft foods in the diet, notably plant foods (© Photo: M. Bas).

Most problematic, perhaps, is that rather than diet, elevated $\delta^{15}N$ levels may represent a negative nitrogen balance due to rapid protein turnover because of illness or starvation prior to death. This signal may come from the mother rather than the child; a study of teeth from 19th century cemeteries in Ireland and London, of poor and malnourished individuals (Beaumont et al. 2015) indicated that $\delta^{15}N$ levels of infants most likely reflect maternal stress such as malnutrition, morning sickness and illnesses such as tuberculosis.

One way of overcoming these problems is studying the isotopic signature of serial micro-samples of dentin in people who survived infancy. Jelmer Eerkens and colleagues (Eerkens – Berget – Bartelink 2011) cut first molars in 5–10 sections, which were related to the individuals' ages. The development of the first molars span a time period from birth to about age 9–10. It is, however, difficult to match the sampling location to a time in the individual's life that is accurate enough to infer weaning times and patterns. Nevertheless, the six sampled individuals show the same types of weaning curves as known from population level studies.

Studies of dental micro-wear (Fig. 1) have recently gained momentum in bioarchaeological studies (El Zaatari et al. 2016; Hillson 2005, 219–223), as they allow inferences on diet and fluctuations in food supplies due to changing climate conditions. Dental micro-wear is caused by abrasive particles in the mouth and repeated pressure between opposing teeth. As dental micro-wear is constantly overwritten (Hillson 2005, 220), it can provide information on the last weeks prior to death (Fig. 1). So far, there are few studies that focus on deciduous teeth (Bas 2017; Mahoney et al. 2016), but Rachel Scott and Siân Halcrow (Scott – Halcrow 2017) have recently outlined their potential for understanding the process and timing of weaning.

To obtain best results in understanding breastfeeding and weaning of prehistoric individuals, the combination of several different methodological approaches is at present most promising.

Trends in later prehistoric and historic Europe

A significant factor in when an infant can be weaned is the availability of appropriate food other than mother's milk, which is nutritious and easily digestible. In later prehistoric Europe, most societies were agriculturalists, but people of the Eurasian steppes were pastoralists that had limited access to domesticated grains and subsided primarily on animal products supplemented by wild plants. Alicia Miller and colleagues (Miller et al. 2017) found a prolonged weaning period completed by four years of age among Bronze Age Eurasian pastoralists. A cross-cultural study differentiating agricultural, pastoral and extractive modes of subsistence found that agriculturalists weaned slightly earlier than pastoralists, but differences between the three groups were smaller than expected (Sellen – Smay 2001).

Francesca Fulminante has recently brought together a large number of isotopic studies (of varying quality) of breastfeeding duration within Europe and the Mediterranean, spanning from prehistory to the Middle Ages, and compared them with historical sources such as Babylonian records, Egyptian papyrus, the Bible and ancient authors (Fulminante 2015). Ancient authors recommend breastfeeding for at least two years (similar to the WHO today[1]), which indicates clearly that many societies recognised the positive relationship between breastfeeding and infant health.

The broad trends identified suggest that from the Neolithic to the Iron Age weaning was completed by about 2–3 years (Fulminante 2015, 41). Two infants at Neolithic Kleinhadersdorf, Austria, aged 1–1.5 years and two years, exhibited a nursing signal in the form of elevated nitrogen values and depleted $\delta^{13}C$ values (Bickle et al. 2013; Neugebauer-Maresch – Lenneis 2015, 174). In a study of dietary patterns in the early Bronze Age Únětice Culture in Poland, the data from two children suggests that milk consumption was lower in the second half of the first year of life and supplementary foods were introduced by about six months (Pokutta – Howcroft 2015, 249). The sample size is too small, however, to be representative. The infant diet at two Iron Age sites in Sweden was compared in a study by Rachel Howcroft, Gunilla Eriksso and Kerstin Liden (Howcroft – Eriksson – Lidén 2012). The cemetery of Bjärby contained children that survived the earliest years of life, whereas at Triberga most had died at six month of age. The team took 124 samples from both cemeteries for carbon and nitrogen isotope testing, from bone and tooth dentin. In both sites, the adult diet contained a considerable marine component, perhaps unsurprising with this particular location; the nitrogen results suggest that there were no substantial differences in the diet of babies between the two sites. Both sites show elevated nitrogen values for the first two years of life, although individual variability was high. Differences between the sexes and between high and low status individuals may account for some of the pattern. The carbon data points to a higher non-protein component in the diet of babies at Triberga compared to Bjärby, which be the result of feeding cereal gruel. The authors suggest that rather than the breastfeeding duration, which was comparable at the sites, the high carbon weaning foods may have contributed to the infant mortality at Triberga (Howcroft – Eriksson – Lidén 2012, 227).

In the Classical, Hellenistic and Roman periods two patterns emerge: a shorter duration of weaning and earlier cessation of breastfeeding at two years old in the centre of the Roman Empire, and more gradual weaning and complete cessation of breastfeeding at the age of around three to four in the provinces (Fulminante 2015, 41). A study of the Roman cemetery from the Isola Sacra (Prowse et al. 2008), for example, plots the nitrogen values of 37 infant rib samples and puts them in the order of estimated age at death. The result is a well known curve with high nitrogen values in the first two years, dropping to the adult mean at around 2–2.5 years of age. A similar pattern emerged at the Greek colonial site of Apollonia Pontica in Bulgaria (Schmidt – Kwok – Keenleyside 2015), although individual values are quite variable.

In the Byzantine and Medieval periods a geographical difference emerged: the eastern Mediterranean breastfed for about three to four years, whereas continental Europe only breastfed between one and three years. Early urban and urban societies breastfeed for the shortest period of time (Fulminante 2015, 42–44).

1) http://www.who.int/topics/breastfeeding/en/ (last accessed 28th September 2017).

In urban early modern Central Europe, breastfeeding was at times so unpopular that few infants were fed appropriately and the infant mortality rate was extremely high.

Breastfeeding alternatives

What were the alternatives if, out of choice or force, women were not able to breastfeed their babies? The WHO claims that 'virtually all mothers can breastfeed, provided they have accurate information, and the support of their family, the health care system and society at large'.[2] If childbirth went wrong, however, and the mother died, the mother is not available for feeding the infant. If nothing medically effective is done to avert death, the estimated maternal mortality today is about 1.5% per birth (Van Lerberghe – De Brouwere 2001, 3). Many infants have died with their mothers in such cases, and the ones that did not, did not have particularly great chances of survival. A study conducted in Nigeria in 1996 found that 69% of live-born infants whose mothers died during birth did not survive to the age of five; the majority of surviving infants were nursed by a close relative (sister or mother) or fed with goat or cow milk (Obed – Agida – Mairiga 2007).

The first alternative to breastfeeding by the own mother is breastfeeding by another lactating mother in the family or wider social group. The term cross-nursing is applied when friends and family breastfeed the baby in the mother's temporary absence, e. g. in the course of babysitting, whilst wet-nursing is usually a permanent replacement for the mother (Fildes 1989). The transition from initially being fed with one's own mother's milk to the milk of a wet nurse carries some risk, as the baby may not have sufficient immunity to the different set of germs the wet nurse carries (Fildes 1986, 204). In addition, the mature milk of the wet nurse is not perfectly matched to a new-born in the sensitive first few weeks.

First records of wet-nursing date to about 2000 BC, from Egypt and Babylonia (Gruber 1989; Stevens – Patrick – Pickler 2009), and wet-nursing developed into a complex social and legal contract-system, linked to the social status of infants and mothers. Only high-status mothers could afford the costs of hiring a wet nurse. Not having to feed their own babies freed them for other social obligations, but also ensured that the temporary postnatal infertility due to lactational amenorrhea was as short as possible. High status women could therefore achieve a quicker succession of births than those of lower status. Historically, this is exemplified by mothers such as Agnes von Waiblingen (1072–1143), the wife of the Babenberger patriarch Leopold III, who gave birth to at least 21 children, allegedly more (Neukam 2011, 58), or the Hapsburg empress Maria Theresia (1717–1780), who, despite her political function, had 16 births (Mraz – Mraz 1979). Wet nurses must have given birth at least once to initiate lactation, and were usually not allowed to feed their own children alongside their higher status nurselings; the chances of survival for the offspring of the wet nurses were slim (Thorley 2015). Despite the status differences, it was often believed that physical and moral qualities were transmitted with the breast milk from wet nurse to the baby (Saari et al. 2016).

Societies that use wet nurses usually exhibit significant social stratification; we can therefore assume that wet-nursing may have developed in tandem with social difference during the Bronze and Iron Ages in Europe. At present, however, there is no way to address wet-nursing with scientific methods and therefore no way to document the practice in European prehistory.

The closest substitute to human milk is animal milk, which was available in societies that bred sheep, goats and cows or horses for their milk. However, human breast milk is adjusted to human needs, and milk of other animals is substantially different. Cow milk, for example,

2) http://www.who.int/topics/breastfeeding/en/ (last accessed 28th September 2017).

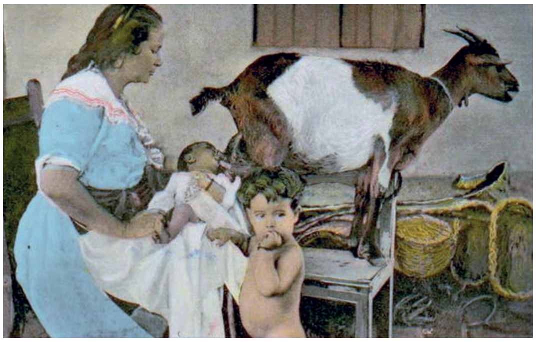

Fig. 2. Using a goat to feed a baby in Havana, Cuba, in 1903 (© Photo: C. Teich).

has a much higher protein content with about 3% and contains micro-nutrients in different rations, as well as allergens. Goat milk is nutritionally closer to human milk, and horse and donkey milk is most similar in composition (Pastuszka – Barlowska – Litwinczuk 2016). Substituting human milk with milk of other species is difficult for babies' bodies, especially in the first weeks. Feeding unpasteurised animal milk further comes with a risk of contamination and the transmission of zoonoses from animals to humans.

Direct suckling from animal teats by infants (Fig. 2) has been immortalised in mythology in the motif of the twin brothers Romulus and Remus being fed by wolves, and has likely had real-life models (Van Esterik 1995). Goats are most suitable to let the child suckle directly (Valenze 2012). The alternative is to milk the animals and feed the baby with spoons, vessels and bottles, which carries an additional risk of contamination. Small spoons that could have been used to feed babies are almost absent in European prehistory. A rare exception is a spoon included in a 4–5-year old's inhumation grave at the Middle Bronze Age cemetery of Pitten, grave 64 (Hampl – Kerchler – Benkovsky-Pivovarová 1981, 50; Teschler-Nicola 1985, 160).

Feeding vessels, however, vessels with a small spout through which liquid can be poured – have been part of the material culture in many prehistoric contexts. Feeding vessels functioned similarly to glass bottles with rubber teats that were introduced in the mid-19th century (Stevens – Patrick – Pickler 2009, 35). They come in many sizes, shapes and decorations; although they generally fit the period-specific style, each piece is unique (Figs 3 and 4). Many of them are stray finds, but some were found in context with children's graves, which led to the idea that they may have been used as feeding vessels for babies and small children. One of the earliest European examples is that of a Linear Pottery Culture (LBK) feeding vessel from Steigra, dating to c. 5500–4800 BC (Meller 2011, 95). It is exhibited in the Halle State Museum of Prehistory, and introduced as a device for caring for the injured, with which medicine and nourishment could be administered. At Aiterhofen, Bavaria, a feeding vessel has been found in a context thought to be a child's grave (Nieszery 1995).

Since Clemens Eibner's seminal article on late Bronze Age feeding vessels (Eibner 1973), more evidence has come to light that supports the association between feeding vessels

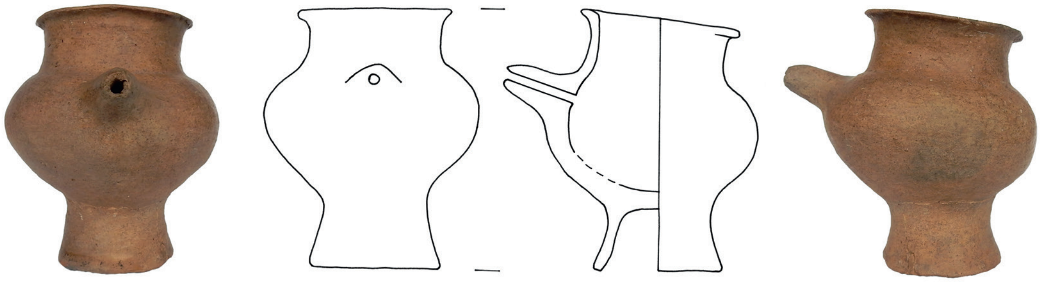

Fig. 3. Late Bronze Age feeding vessel, c. 12 cm, from the cremation grave of a 0–6-year-old from Vienna, Mühlsangergasse (Csokorgasse, Kloiber 1942; Wanschura 1942) (© Wien Museum, Photo and drawing: K. Rebay-Salisbury).

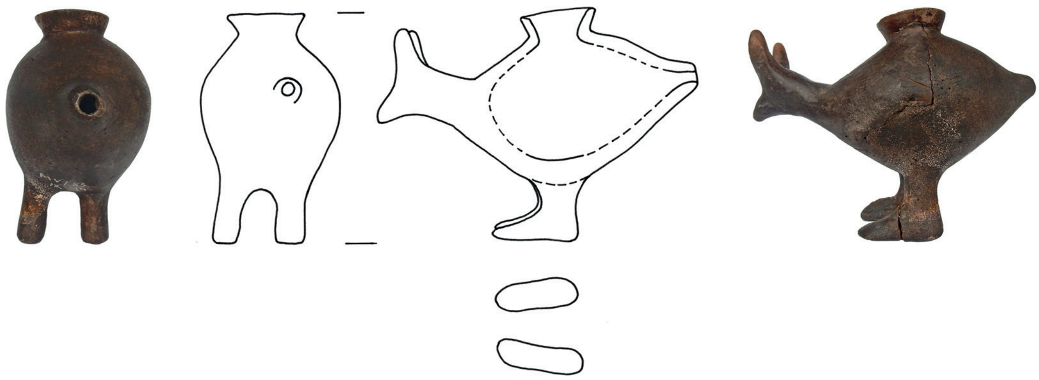

Fig. 4. One of four feeding vessels from a cremation grave from Vösendorf, Lower Austria, c. 9.5 cm (LADENBAUER-OREL – SEEWALD 1950: 31) (© Wien Museum, Photo and drawing: K. Rebay-Salisbury).

and children's graves. The late Bronze Age cremation cemetery of Franzhausen-Kokoron, Austria, contained only a single feeding vessel. It was found in the urn of Grave 344, together with cremated bones of a 0–6-year-old and fragments of a bronze pin and bracelet (LOCHNER – HELLERSCHMID 2016, Grab 344). Bronze Age feeding vessels from Slovakia have recently been brought together (FURMÁNEK – MITÁŠ 2007). Several feeding vessels have further come to light at the late Bronze Age cremation cemetery of Budapest-Békásmegyer (KALICZ-SCHREIBER 2010), but many of the graves did either not contain any bone material or were not sufficient to determine sex and/or age. One feeding vessel was associated with a child of the infans II group (Grave 58), one with cremated bones of a mature adult (Grave 441).

At the early Iron Age cemetery of Dietfurt-Tennisplatz, Germany, a feeding vessel was found at the feet of the burial of a small child (infans I/age not determinable) in inhumation grave 80 (RÖHRIG 1994, 168). In the neighbouring site Dietfurt-Tankstelle, a feeding vessel was associated with the burial of an approximately one-year-old child (AUGSTEIN 2015, 133, pl. 69/2).

The early Iron Age burial mound 81 from Führholz, Austria (WEDENIG 1993), contained the cremation burial of an adult, probably female individual, with iron knives and remains of a bronze bracelet. Amongst the ten ceramic vessels in this grave was a small feeding vessel. An association between feeding vessels and children's graves could not be demonstrated at the early Iron Age site of Statzendorf (REBAY 2006, 106–107), in part because none of the eight graves containing feeding vessels had human remains preserved. Grave A36 also contained an iron axe, which may point to a male burial, although it could have been a young boy. In the course of the early Iron Age, feeding vessels develop from simple, functional forms to zoomorphic, ostentatious vessels, which may have assumed a different function such as libination – the act of pouring a liquid as a sacrifice to a deity (NEBELSICK 1997, 118). The much larger, bull-headed ceremonial vessels of the early Iron Age are more often associated with male graves. Written records, depictions and the vessels themselves attest that feeding vessels of various shapes and forms were used throughout the medieval and modern periods (EIBNER 1973, 190–193).

How can we test what the feeding vessels actually contained? Experimental work has confirmed that it is possible to feed small children with liquid from feeding vessels (Fig. 5). The diameter of the hole through which the liquid is poured is quite variable, but in some cases, only a few millimetres wide – large enough for liquids, but not for solid food such as porridge or gruel. Organic residue analysis may help to trace organic molecules of foodstuffs

Fig. 5. Experimental use of a feeding vessel: Peter Grömer feeding his 14-months-old son in Hallstatt in 2003 (© Photo: A. and D. Kern).

absorbed into archaeological pottery and preserved in the ceramic matrix. Chromatographic techniques, mass spectrometry and combustion-isotope ratio mass spectrometry can be applied to characterise the compounds and differentiate dairy fats from fats that come from the animal carcass, e. g. when cooking a soup from bones and meat. Organic residue analysis can identify the difference between the processing of ruminant (cattle, sheep and goat) and non-ruminant (pig) carcass products. Dairy fats from milk can further be separated isotopically from fats from the animal carcass (Dunne 2017; Evershed 2008a; Evershed 2008b).[3] It will remain unclear, however, if feeding vessels were used for new-borns or only after weaning has begun.

The final, and nutritionally least advisable option, is to feed the new-born grain based substitutes, pap – bread soaked in water, milk or broth, or porridge and gruel – cereals cooked in water, milk or broth (Obladen 2014). In the early Modern Period, when breastfeeding was unpopular in Central Europe, such substitution was even translated to art. A few manger scenes depict Saint Joseph cooking porridge, right after his birth. Contemporary written sources attest that it was indeed intended for the baby, and not to fortify the mother for breastfeeding (Walsh 2004).

At the time Mozart's first son was born (1783), breastfeeding was considered inappropriate for high status women, but it was also believed that wet nurses could transmit character traits to the babies they fed. In a letter to his father (Mozart 1924 [1783]) Mozart details that he will not allow his wife to nurse his baby, and yet reluctantly, he was talked into appointing a wet nurse. The midwife, the mother in law and others had urged him to do so, since children 'raised by water' have little chance of survival. He mentions that he himself and his sister had been raised by water, and it has not harmed them – he makes no mention, however, that five of his siblings died in the first few months of life with this feeding practice. Sadly, appointing a wet nurse has not helped his firstborn Raimund Leopold Mozart, who died two months after birth of diarrhoea (Scherbaum 2003, 2).

Conclusion

Feeding practices of babies and small children provide an exceptionally rich example of how a mix of natural processes and cultural choices builds the foundations of societies. The complex interdependencies between the mother's and the baby's physiology during pregnancy, birth and the early childrearing phase underline the importance of breastfeeding for both. The natural, and in the course of (pre-)history increasingly cultured, environmental setting, as well as the nutritional background it provides, influence breastfeeding and weaning behaviour. The

3) In the course of the ERC project 'The value of mothers to society', we are currently analysis sample from nine Bronze and Iron Age feeding vessels in collaboration with the Organic Chemistry Unit at Bristol University (Rebay-Salisbury et al. in prep).

availability of supplementary fluids and foodstuffs such as cereals and animal milk is crucial to the successful supplementation and timing of the eventual replacement of breast milk as the infant grows.

The duration of breastfeeding and the pattern of the weaning process have been investigated for many contemporary and archaeological societies. For the latter, a combination of different bio-anthropological approaches such as studying enamel hypoplasias, Harris lines, isotope ratios and dental micro-wear have proven fruitful. The multitude of isotopic studies in particular have given rise to an increasingly robust understanding of the variability of breastfeeding and weaning within communities, and the broader patterns that emerge between different societies. In reading conclusions of individual studies, however, attention has to be paid to differences in the applied methods, the choice of isotopic systems for analysis, the sampled skeletal or dental parts and the way bone turn-over rates were incorporated in the interpretations. It is not enough to just compare the months and years mentioned in the conclusion – the results have to be re-evaluated in the light of new methodological insights.

Chances of survival for a new-born, whose mother was not available to breastfeed, were slim. Cross- and wet-nursing are the best alternatives, although they too come with health risks, followed by feeding animal milk and grain-based substitutes. Feeding vessels from Neolithic to modern contexts testify to attempts of caring for babies, small children and the sick. The age of the infant is a crucial factor for whether and if such alternatives could be tolerated, despite the risks of contamination and inadequate nutrition. Despite high infant mortality, some individuals across (pre-)history have always been incredibly resilient.

Acknowledgments

I would like to thank Daniela Kern and Roderick Salisbury for their willingness to discuss matters of infant feeding, and Julie Dunne for her introduction into the world of organic residue analysis. Marlon Bas has proofread the article and will pursue his studies on micro-wear signatures of deciduous teeth on prehistoric material. He and Karina Grömer have generously provided illustrations for this article. This review was undertaken within the project 'The value of mothers to society: responses to motherhood and child rearing practices in prehistoric Europe', funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 676828).

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