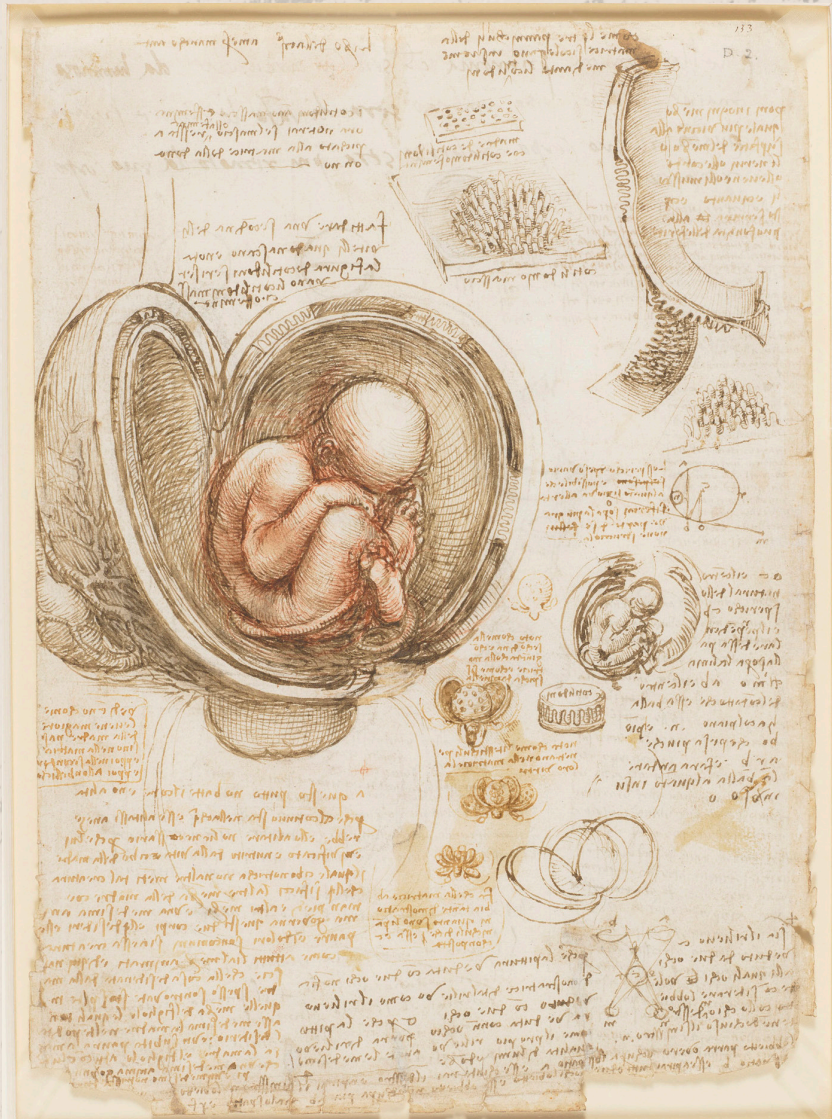


# HEALTH IN TRANSITION

Translating developmental origins of health and disease science to improve future health in Africa



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# 6

## THE FUNDAMENTAL IMPORTANCE OF BREASTFEEDING FOR HEALTH AND DEVELOPMENT

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How an infant is nourished in early life is central to the DOHaD hypothesis regarding the later onset of chronic non-communicable diseases, especially where feeding practices result in either stunting of growth or excessive weight gain. This chapter reviews the evolutionary history of the origins of breastfeeding and summarises studies evaluating its benefits.

Mammals take their name from the Latin word *mamma* for the teat. This root also gave rise to the term mammary gland, which, along with the associated behaviour of suckling offspring, is a universal feature of all mammals alive today. Human cultural practices over the past 5 000 years or so, notably including the exploitation of milk from other mammals and eventual development of milk formulae, have exerted a major impact on breastfeeding. The greatest effects have occurred in industrialised

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nations, where many mothers breastfeed for only a few months, if at all, and breastfeeding beyond a year is rare. Because of pervasive cultural influences, it is difficult to establish a 'natural' period for human breastfeeding that would include an initial period of exclusive breastfeeding, followed by a phase of supplementary feeding. Information from modern hunting-and-gathering populations and other non-industrialised societies indicate an average total duration of at least two-and-a-half years, with a wide range of variation extending up to around five years.

Whenever tested, the benefits of breastfeeding for infants have been found to show a dose-response relationship, with the greatest benefits shown with breastfeeding for two to three years. Breastfeeding is also beneficial for mothers. There have been recent claims that over-enthusiastic promotion of breastfeeding, given the label 'activism' is both unkind and unwarranted. While it is true that women who, for whatever reason, are unable to breastfeed, need support and not bullying, it is both unjustifiable and irresponsible to dismiss the very substantial scientific evidence that now exists for the undoubted benefits of breastfeeding.

## Ancient origins of breastfeeding

For a biologist, humans are mammals – not simply an arcane statement about our place in the animal classification, but the implication is far more profound: We possess all the key biological features that distinguish mammals from other members of the animal kingdom. Two of those features – the presence of hair and suckling (called breastfeeding or nursing in humans) – are easily recognised. Less obvious is the fact that they have linked evolutionary origins.

Hair is a feature that distinguishes mammals from all other vertebrates (animals with backbones). Whereas fish, amphibians and reptiles lack hair and may have scales instead, birds have feathers. By contrast, mammals typically have a coat of hair covering most of the body surface, although in some cases a secondary development has led to reduction or loss. Aquatic mammals such as dolphins and manatees, for instance, are often virtually bare, and burrowing mole-rats have also lost most of their hair. Humans also count among the special cases, as famously proclaimed in the title of Desmond Morris's 1967 bestseller, *The Naked Ape*.<sup>2</sup> Because hair is confined to mammals and is present in some form in virtually all species, it seems most likely that a covering of body fur emerged early in their evolution and then underwent a secondary reduction in a few lineages. However, it is theoretically possible that hair evolved separately in several different lineages. Evolutionary

2 Morris, D. 1967. *The Naked Ape: A Zoologist's Study of the Human Animal*. London: Jonathan Cape.



biologists have recognised many cases of the independent evolutionary origin of features – known as *convergent evolution*.

In reconstructing evolutionary history, a crucial source of information is the fossil record. At first sight, it might seem highly unlikely that we could ever find fossil evidence for the evolutionary origin of hair, given that preservation of remains is mostly limited to hard structures such as teeth and bones. However, under certain conditions, traces of body hair may be found with mammal fossils, for example when a shadow-like outline of the body is preserved, and sometimes actual carbonized filaments provide direct indications of hair. Such direct evidence has been found with well-preserved fossil specimens of very early mammals. Hair has been reported for several different Cretaceous mammals from China dating back about 125 million years, and the earliest evidence comes from mammals that lived 165 million years ago.<sup>3</sup> It is generally accepted that mammals originated from mammal-like reptiles some 200 million years ago, and indirect evidence suggests that hair may have evolved even earlier. Before the first appearance of mammals in the fossil record, some advanced mammal-like reptiles had pits on their snouts interpreted as having an association with whiskers, which are tactile hairs.

Because living mammals typically have hair, some classifications once used the name *Pilosa* (from the Latin word, *pilus* for hair) for the entire group. So at one point biologists could have ended up calling mammals ‘pilosans’, but the other striking feature of mammals, suckling, is even more fundamental. It is truly universal, without a single exception. Whereas some mammals have virtually lost their hair, not one species has secondarily lost the possession of milk-producing *mammary glands* and suckling. All female mammals produce milk to feed their infants by suckling. Modern classifications began with Linnaeus, who introduced stability into a rather chaotic free-for-all. Writing a century before Darwin (and hence

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- 3 Ji, Q., Luo, Z.X., Yuan, C.X., Wible, J.R., Zhang, J.P. & Georgi, J.A. 2002. The earliest known eutherian mammal. *Nature*, 416, April:816-822. [https://doi.org/10.1038/416816a]; Luo, Z.X., Ji, Q., Wible, J.R. & Yuan, C.X. 2003. An early Cretaceous tribosphenic mammal and metatherian evolution. *Science*, 302(5652), December:1934-1940. [https://10.1126/science.1090718]. Rougier, G.W., Ji, Q. & Novacek, M.J. 2003. A new symmetrodont mammal with fur impressions from the Mesozoic of China. *Acta Geologica Sinica*, 77(1), March:7-14. [https://doi.org/10.1111/j.1755-6724.2003.tb00104.x]; Martin, T., Marugán-Lobón, J., Vullo, R., Martín-Abad, L.Z.X. & Buscalioni, A.D. 2015. A Cretaceous eutriconodont and integument evolution of early mammals. *Nature*, 526:380-384. [https://doi.org/10.1038/nature14905]; Ji, Q., Luo, Z.X., Yuan, C.X. & Tabrum, A.R. 2006. A swimming mammaliaform from the Middle Jurassic and ecomorphological diversification of early mammals. *Science*, 311(5764), February:1123-1112. [https://doi.org/10.1126/science.1123026].

well before the advent of evolutionary theory), Linnaeus chose to use the label Mammalia rather than Pilosa. It has now emerged that his emphasis on suckling rather than hair in his influential classification was more political than biological. Science historian Londa Schiebinger discovered that Linnaeus actively campaigned to encourage Swedish women to breastfeed their babies, and distributed a pamphlet about the topic.<sup>4</sup>

It is important to note that both hair and suckling are more basic and ancient than live birth (*vivipary*). Among modern mammals, a few unusual representatives in Australasia known as monotremes – platypuses and spiny anteaters – have retained the ancient pattern of laying eggs; but they have hair and provide milk for their infants. However, monotremes do not possess teats, and the milk simply oozes from pores on the mother's belly. Nonetheless, because all modern mammals provide milk for their infants, it seems very likely that their common ancestor already did so. Live birth doubtless evolved later, after the monotremes had branched away, originating somewhere between the origin of all mammals and the common ancestor that gave rise to marsupials and placentals, around 150 million years ago.<sup>5</sup>

Hair and suckling, however, share more than just their ancient origins. Different kinds of skin glands evolved along with the hair. Biologists recognise three basic types: sweat-producing *eccrine glands*, scent-producing *apocrine glands*, and oil-producing *sebaceous glands*.<sup>6</sup> The most likely explanation is that milk-producing glands of ancestral mammals evolved from sebaceous glands. Because the oily secretions of these glands help maintain fur condition, they have a direct connection to hair follicles. Comparative evidence indicates that milk-producing glands were also connected originally with hair follicles, providing a clue to their origin. Accordingly, in ancestral mammals, skin glands producing moist secretions underwent gradual conversion to mammary glands that yielded milk containing a mixture of nutrients and antibiotics.<sup>7</sup> Milk is often seen simply as a source of infant nourishment, and that can lead to the mistaken belief that artificial kinds of milk

4 Schiebinger, L. 1993. Why mammals are called mammals: Gender politics in eighteenth-century natural history. *American Historical Review*, 98(2), April:382-411. [<https://doi.org/10.2307/2166840>].

5 Martin, R. 2020. How We Do It: The evolution and future of human reproduction. *Psychology Today*. [<https://www.psychologytoday.com/intl/blog/how-we-do-it>].

6 Ibid.

7 Oftedal, O.T. 2002. The mammary gland and its origin during synapsid evolution. *Journal of Mammary Gland Biology & Neoplasia*, 7(3), August:225-252. [<https://doi.org/10.1023/A:1022896515287>].

only need to deliver the appropriate nutrients. Antibiotics contained in a mother's milk provide the baby's first line of defence against disease agents.<sup>8</sup>

As already indicated, it is reasonable to infer that in the common ancestry of all mammals, mothers suckled their offspring. However, we cannot be sure of this because similar functional requirements often lead to similar adaptations through convergent evolution. Even a complex feature such as suckling could have evolved separately in different lineages. When the ancestors of dolphins and whales returned to life in water, for instance, they eventually developed a streamlined body form that convergently resembles that of a fish.<sup>9</sup> Similarly, suckling might not have evolved just once, so how can we go about checking this? In this case, there is not even a remote possibility that we might be able to test the inference with fossil evidence as we were able to do with hair.

It so happens that this is a truly remarkable case in which genetic evidence – considerably reinforced by complete genome sequences generated for an increasingly large and diverse sample of mammals – has yielded a valuable new perspective in recent years. A distinctive universal feature of mammal milk is the presence of special proteins known as *caseins*, which are unique to mammals. Genes that produce caseins are active only in mammary glands. Complete genomes have already been sequenced for an egg-laying monotreme (platypus), a marsupial (opossum), and several placental mammals (e.g. cow, dog, mice, rat, human). An evolutionary tree based on deoxyribonucleic acid (DNA) sequences of casein genes reveals that the most plausible explanation is that there was only a single origin in the common ancestor that gave rise to monotremes, marsupials, and placentals. At the outset, only a single copy of the casein gene was present, but subsequent gene duplications have generated additional copies. The genome of humans, like that of other primates, rabbits and rodents, includes five copies of the casein gene. Reconstruction of the evolutionary history of the casein gene family has resoundingly confirmed the interpretation that suckling evolved only once in or before the common ancestor of all mammals alive today.<sup>10</sup>

8 Lönnerdal, B. 1995. Breast milk: a truly functional food. *Nutrition*, 16(7-8), July-August:509-511. [[https://doi.org/10.1016/s0899-9007\(00\)00363-4](https://doi.org/10.1016/s0899-9007(00)00363-4)]; Newman, J. 1995. How breast milk protects newborns. *Scientific American*, 273(6), December:76-79. [<https://doi.org/10.1038/scientificamerican1295-76>].

9 Martin, 2020.

10 Rijnkels, M., Le, T. & Thomas, J. 2005. Evolution and regulation of the casein gene cluster region: a genomics approach. *Journal of Dairy Science*, 88(Supplement 1):76-77; Lemay, D.G., Lynn, D.J., Martin, W.F., Neville, M.C., Casey, T.M., Rincon, G., Krivenseva, E.V., Barri, W.C., Hinrichs, A.S., Molenaar, A.J., Pollard, K.S., Maqbool, N.J., Singh, K., Murney, R., Zdobnov, E.M., Tellam, R.L., Medrano, J.F., German, J.B. & Rijnkels, M. 2009. The bovine lactation genome: insights into the

Additional, albeit less striking, evidence is available from milk sugars regarding the evolution of suckling in the earliest mammals. Comparisons across mammals indicate that milk-specific sugars were already present in the common ancestor of extant mammals more than 200 million years ago. At that stage, however, the sugars present in milk were still quite diverse because different kinds have come to dominate in modern monotremes, marsupials and placentals, respectively. In placental mammals, including humans, lactose is universally the principal milk sugar, so it can be concluded with some confidence that this sugar was dominant in their common ancestor over 100 million years ago.

## Babies' brains develop better with breastfeeding

The extensive evolutionary history of milk production and suckling, beginning with the first mammals some 200 million years ago, demands our attention and respect. Natural selection throughout that significant fraction of the history of life on earth – about a third of the total period for which multicellular organisms have existed – has surely deeply embedded the physiology of milk production (lactation) in mammals and honed the adaptations of individual species. It is therefore only to be expected that both mothers and infants must possess fine-tuned adaptations for suckling and sucking, respectively. The biological starting-point for considering breastfeeding under current living conditions worldwide must surely be the expectation that any departure from the natural pattern for which we are adapted is likely to have adverse effects. It is, therefore, crucial to try to establish what the natural pattern was for pre-agricultural societies over 10 000 years ago when the ancient lifestyle of gathering-and-hunting was still ubiquitous. Moreover, we need to determine what changes have been brought about by social modification of infant rearing. Perhaps the most obvious and influential change that has occurred is the switch from exclusive breastfeeding to bottle-feeding with infant formula.

Numerous advantages of breastfeeding over bottle-feeding have been reported in an extensive literature. One predominant theme has been the oft-repeated finding that breastfed babies consistently show significant advantages over bottle-fed babies in a variety of mental tests. It must be emphasised that the observed differences are generally quite small and that there is considerable overlap in test scores between breastfed and bottle-fed babies. Indeed, some studies have failed to find a significant difference, and there is a systematic problem in that studies depend on correlations without any kind of experimental confirmation. Accordingly, the evidence has often been disparaged as 'only circumstantial'.

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evolution of mammalian milk. *Genome Biology*, 10(4):1-18. [<https://doi.org/10.1186/gb-2009-10-4-r43>].

Moreover, correlational studies are subject to the ever-present danger that observed effects might be influenced by confounding factors that have not been taken into account by the investigator. It has, for instance, often been reported that mothers from higher-income brackets are more likely to breastfeed. Babies reared in wealthier homes are, however, likely to benefit from many advantages that can positively influence mental test results. Hence, an apparent correlation between breastfeeding and mental test scores may be driven by the confounding factor of socio-economic status. Statistical studies that examine correlations between mental test scores and breastfeeding must, therefore, use appropriate methods to detect and remove the effects of confounding variables.

Reports indicating small but significant deficits in brain development in bottle-fed infants began to emerge in the 1970s. A landmark 1978 paper by Bryan Rodgers assessed a 1946 birth cohort of children monitored by the National Survey of Health and Development in the UK.<sup>11</sup> This study stands out because particular care was taken to control for confounding factors. Rodgers conducted attainment tests with over 2 000 children in the cohort when they were eight to 15 years old. One thousand one hundred and thirty-three children were entirely bottle-fed, and 1 291 were never bottle-fed. Low scores were generally more likely for bottle-fed than for breastfed children. In the bottle-fed group, 14.4 per cent (128 of 890) scored 39 points or less on the 15-year reading test, compared with only 8.4 per cent (90 out of 1 071) in the breastfed group. After taking differences in the family background into account, attainment scores for the bottle-fed group were found to be still statistically significant ( $p < 0.001$ ). However, on average bottle-fed children scored only one to two points less than breastfed children over a range extending from 25 to 75 points. Many subsequent studies reported similar small differences, with bottle-fed children showing somewhat lower average scores on intelligence tests and a somewhat higher incidence of learning deficits.

In the meantime, sophisticated statistical techniques have become available to control for confounding factors in epidemiological studies. Appropriate analyses of survey data by numerous investigators now leave little doubt that mental development is linked to breastfeeding. There has also been increasing uses of meta-analyses in which results from several published studies are examined together to identify consistent findings. By 1999, James Anderson and colleagues

11 Rodgers, B. 1978. Feeding in infancy and later ability and attainment: a longitudinal study. *Developmental Medicine and Child Neurology*, 20(4), August:421-426. [<https://doi.org/10.1111/j.1469-8749.1978.tb15242.x>].



were able to conduct a judicious combined analysis of 20 previous studies.<sup>12</sup> They took particular care to control for confounding factors in testing for a convincing relationship between mental test scores and breastfeeding effects. The overall outcome was this: Breastfed babies tested between six months and two years of age consistently showed significantly higher levels of mental function than bottle-fed babies. Moreover, the benefits of breastfeeding proved to be particularly pronounced for premature babies.

## Key components of milk

Mammalian milk contains so many individual constituents that it is a challenging task to identify those that are important and should, therefore, be appropriately replicated in any artificial milk formula. Indeed, much research is still needed to recognize crucial components. Milk fats (lipids) alone show a bewildering diversity. However, the study of human milk ingredients has yielded considerable evidence for the special importance of a particular class of complex lipids: long-chain polyunsaturated fatty acids. Simply stated, polyunsaturated fatty acids can form multiple additional chemical bonds, whereas saturated fatty acids do not. This basic structural distinction has practical significance: polyunsaturated fatty acids, including long-chain polyunsaturated fatty acids, have a lower melting point and remain liquid at body temperature. One reflection of this is that long-chain polyunsaturated fatty acids are important structural components of cell membranes. They are especially well represented in nerve cells, so an adequate supply is essential for optimal development and function of the nervous system. Nutritional researchers Susan Carlson, Michael Crawford, and Stephen Cunnane have particularly emphasized the importance of long-chain polyunsaturated fatty acids for normal development of the brain during pregnancy and breastfeeding.<sup>13</sup> Two prominent examples are arachidonic acid (AA) and docosahexaenoic acid (DHA). AA and DHA are major ingredients of nutritional supplements containing

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- 12 Anderson, J.W., Johnstone, B.M. & Remley, D.T. 1999. Breast-feeding and cognitive development: a meta-analysis. *American Journal of Clinical Nutrition*, 70(4), October:525-535. [<https://doi.org/10.1093/ajcn/70.4.525>].
  - 13 Carlson, S.E. 1999. Long-chain polyunsaturated fatty acids and development of human infants. *Acta Paediatrica*, 88(430), August:72-77; Carlson, S.E. 2001. Docosahexaenoic acid and arachidonic acid in infant development. *Seminars in Neonatology*, 6(5), October:437-449. [<https://doi.org/10.1053/siny.2001.0093>]; Cunnane, S.C. & Crawford, M.A. 2003. Survival of the fattest: Fat babies were the key to evolution of the large human brain. *Comparative Biochemistry & Physiology A*, 136(1), September:17-26. [[https://doi.org/10.1016/S1095-6433\(03\)00048-5](https://doi.org/10.1016/S1095-6433(03)00048-5)]; Cunnane, S.C. 2005. *Survival of the Fattest: The Key to Human Brain Evolution*. Hackensack, NJ: World Scientific.

omega-6 and omega-3 fatty acids. Both are key components of nerve cells, and DHA is also crucial for light-sensitive cells in the retina of the eye.

It is unclear whether a growing human baby can manufacture all the long-chain polyunsaturated fatty acids it needs or whether some degree of supply from the mother is essential. Given the unique developmental demands of the unusually large human brain after birth, these unsaturated fatty acids are in all likelihood crucial ingredients of human milk. It is certainly true that long-chain polyunsaturated fatty acids are well represented in human milk. However, as Lauren Milligan and Richard Bazinet showed in a 2008 paper, they are well represented in primate milk in general, and the increased demands of the enlarged human brain are not reflected by a distinctively higher level of long-chain polyunsaturated fatty acids in human milk.<sup>14</sup> Perhaps the special needs of the growing human brain are met by providing enough milk to meet the overall need for long-chain polyunsaturated fatty acids. Regardless of the findings for non-human primates, cow's milk contains only trace amounts of long-chain polyunsaturated fatty acids, a cause for concern if these unsaturated fatty acids play a key role in brain development, as milk formulas are commonly based on cow's milk.

It is highly likely that long-chain polyunsaturated fatty acids stored during fetal development contribute to human brain growth after birth. Rapid brain growth during the first year of life is connected with an unusual feature of human neonates: their striking plumpness. In an average human newborn weighing around seven-and-a-half pounds, fat tissue accounts for over a pound, around 14 per cent of the total. Human babies at birth are among the plumpest found among mammals and look markedly different from the scrawny newborns of other primates, such as chimpanzees and rhesus monkeys. The proportion of fat tissue in newborn human matches that in mammals living under arctic conditions, and exceeds the level found in baby seals. Stephen Cunnane and Michael Crawford suggested a connection between the unusual plumpness of newborn human infants and long-chain polyunsaturated fatty acids: Stored fat may contain a reserve supply to support brain development.<sup>15</sup> It is also possible that early provision of suitable complementary foods rich in these fatty acids could boost availability for brain development in human infants.

14 Milligan, L.A. & Bazinet, R.P. 2008. Evolutionary modifications of human milk composition: evidence from long-chain polyunsaturated fatty acid composition of anthropoid milks. *Journal of Human Evolution*, 55(6): September:1086-1095. [<https://doi.org/10.1016/j.jhevol.2008.07.010>].

15 Cunnane & Crawford, 2003; Cunnane, 2005.

Because cow's milk has only trace amounts of long-chain polyunsaturated fatty acids, there is a possibility that bottle-feeding could lead to deficient development of an infant's nervous system. It is known that blood concentrations of long-chain polyunsaturated fatty acids are higher in breastfed than bottle-fed infants. Circumstantial evidence reported in various studies also indicates that development of the nervous system may suffer deficits in bottle-fed infants. Results reported for infants born after full-term pregnancies have been mixed, but for preterm infants born after an unusually short pregnancy, there is convincing evidence that a shortage of long-chain polyunsaturated fatty acids in artificial milk is detrimental. Several meta-analyses have failed to find a significant difference between breastfed and bottle-fed infants born at term, so the jury is out regarding a general need to supplement milk formulae with these unsaturated fatty acids.<sup>16</sup> By contrast, there is convincing evidence that any milk given to premature babies should contain adequate quantities of these important fatty acids.

The key point is that the fetus only stores fat during the last three months of pregnancy. Accordingly, infants born well before the due date have unusually limited fat reserves and lack the customary plumpness; their need for long-chain polyunsaturated fatty acids supplied in milk is hence considerably greater. Because of mounting evidence that long-chain polyunsaturated fatty acids in milk may be important for normal development of the nervous system, especially in premature babies, AA and DHA have been gradually added to artificial milk in various countries. In 2002, the USA Food and Drug Administration belatedly approved the addition of AA and DHA to milk formula. Artificial milk enhanced in this way was, however, not approved for preterm infants, despite this group having the greatest need for supplementation with long-chain polyunsaturated fatty acids. The basic problem has been that evidence indicating the vital importance of AA and DHA in human milk has generally been indirect. That evidence, however, is a smoking gun and an urgent topic for targeted medical investigation.

Almost all evidence indicating that breastfeeding is advantageous for a baby's mental development is circumstantial, inevitably because ethical considerations

- 16 Simmer, K., Patole, S. & Rao, S.C. 2008. Longchain polyunsaturated fatty acid supplementation in infants born at term. *Cochrane Database of Systematic Reviews*, 3(CD000376):1-28; Alshweki, A., Muñuzuri, A.P., Baña, A.M., De Castro, M.J., Andrade, F., Aldamiz-Echevarría, L., Sáenz de Pipaón, M., Fraga, J.M. & Couce, M.L. 2015. Effects of different arachidonic acid supplementation on psychomotor development in very preterm infants; a randomized controlled trial. *Nutrition Journal*, 14(1), September:1-11. [<https://doi.org/10.1186/s12937-015-0091-3>]; Jasani, B., Simmer, K., Patole, S.K. & Rao, S.C. 2017. Long chain polyunsaturated fatty acid supplementation in infants born at term. *Cochrane Database of Systematic Reviews*, 3(CD000376):1-52. [<https://doi.org/10.1002/14651858.CD000376>].

generally rule out experiments of any kind. One key experimental study, however, does provide convincing evidence that supplementation of milk formula with the polyunsaturated fatty acids DHA and AA enhances mental development. In 2000, a team of researchers led by Eileen Birch assessed the effects of adding DHA and AA for four months to a commercial milk formula fed to infants.<sup>17</sup> This experimental approach eliminated many of the confounding factors that bedevil comparisons between breastfeeding and bottle-feeding. Infants in the study were assessed with standard developmental tests at four, 12, and 18 months of age. For 18-month-old infants, adding both DHA and AA to formula resulted in an average increase of seven points on a standard scale of mental development. By contrast, no significant effects were found for muscle activity or general behavioural performance. This study convincingly establishes a causal connection between DHA and AA in human milk and brain development.

While breastfed infants have been shown to perform better on mental tests than bottle-fed babies, it has rarely been asked whether this advantage persists into adulthood. Filling this gap, in 2002, epidemiologist Erik Mortensen and colleagues published results from a long-term study of breastfeeding and IQ in more than 3 000 cases.<sup>18</sup> In the study, the duration of breastfeeding was divided into five categories (less than one month, two to three months, four to six months, seven to nine months, and more than nine months), using information the mothers provided when their babies were one year old. Intelligence tests were conducted when those babies had become adults. Mortensen and colleagues took no fewer than thirteen potential confounding factors into account:

- ☐ social status and education of parents;
- ☐ marital status;
- ☐ mother's height, age, and weight gain during pregnancy;
- ☐ cigarette consumption during the last third of pregnancy;
- ☐ the number of pregnancies;
- ☐ estimated gestational age;

17 Birch, E.E., Garfield, S., Hoffman, D.R., Uauy, R. & Birch, D.G. 2000. A randomized controlled trial of early dietary supply of long-chain polyunsaturated fatty acids and mental development in term infants. *Developmental Medicine and Child Neurology*, 42(3), March:174-181. [<https://doi.org/10.1017/s0012162200000311>].

18 Mortensen, E.L., Michaelson, K.F., Sanders, S.A. & Reinisch, J.M. 2002. The association between duration of breastfeeding and adult intelligence. *Journal of the American Medical Association*, 28(18), May:2365-2371. [<https://doi.org/10.1001/jama.287.18.2365>].

- birth length and weight; and
- indicators of complications during pregnancy and birth.

Even after allowing for all of these factors, the duration of breastfeeding was found to be significantly associated with higher adult scores in various intelligence tests.

## Influence of breastfeeding duration

Although numerous studies have revealed a consistent relationship between breastfeeding and mental function, some studies have reported no significant effect. However, it is notable that no study has ever reported a *negative* relationship between breastfeeding and mental test scores, which would surely be expected if the discrepancy between studies were solely attributable to chance variation. One reason for continuing doubts about a connection between breastfeeding and mental function is that the results, although usually significant with adequate sample sizes, are typically relatively small. Even more important, however, is general vagueness about the *duration* of breastfeeding in published studies. Although the category of exclusive bottle-feeding is easily defined and applied, the category 'breastfeeding' may mean anything between mothers nursing a baby for only a few weeks and mothers that do so for three years or more. In modern industrialised countries, mothers commonly stop breastfeeding after a few weeks or months. Numerous investigators did not attempt to determine the duration of breastfeeding and compared exclusively bottle-fed babies with babies in the catch-all category 'ever breastfed'. If mental test scores are compared between never breastfed babies and infants that have been breastfed for only a few weeks or months, it is hardly surprising that any differences found are marginal.

Given the very extensive evolutionary history of suckling, one key question that must be asked is how long breastfeeding would have lasted on average in early human societies before the advent of settled communities and agriculture some 10 000 years ago. Although the fossil record provides no clues to suckling behaviour in the past, we can draw some instructive conclusions from comparative studies, starting with a survey of mammals in general.

Beginning with birth and ending with weaning, every mammal mother suckles her infants for a certain amount of time, called the *lactation period*. In many species, the suckling duration is remarkably constant. A house-mouse mother typically suckles her pups for 22 days, a rat for 31 days, and a tree-shrew for 35 days. In other species, particularly in large-bodied mammals with single infants, the lactation period is quite variable. As humans are large-bodied mammals, appreciable variation in the lactation period is only to be expected. In all modern human societies, culture has,

however, greatly influenced mothering. Consequently, it is no easy task to decide what is ‘natural’ for our species.

In search of clues, an instrumental first step is to survey mammals in general – with a special focus on primates – to identify general principles as a background to human origins.<sup>19</sup> Mice, rats, tree-shrews, and other similar mammals have a primitive breeding pattern, with short pregnancies and poorly developed (altricial) offspring. Suckling stops sharply at a standard interval after birth, and there is an abrupt shift to solid foods. Primates, by contrast, give birth to well-developed (precocial) offspring after long pregnancies. In many cases, particularly with larger-bodied species, suckling periods are rather variable and associated with a gradual transfer to solid foods. Suckling duration varies from species to species among primates, from a fairly constant 45 days in a two-ounce mouse lemur to a variable period averaging around six-and-a-half years in a 90-pound Bornean orangutan. The maximum duration of over seven-and-a-half years reported for a Bornean orangutan is seemingly the longest recorded among mammals.<sup>20</sup>

As is the case for many other features, suckling durations are scaled to body size across mammals: the larger the mammal, the longer the average lactation period. Primates, however, generally suckle infants for a comparatively long time even in comparison to mammals of similar body size. There is also a marked disjunction between groups (grade shift) in the scaling relationship among primates. At any given body size, higher primates (monkeys and apes) generally suckle longer than lower primates (lemurs, lorises and tarsiers). It seems difficult to decide on an average weaning age for which humans are biologically adapted, confronted with such complexity. Seeking a biological clue to human weaning age, in a 2004 paper anthropologist Katherine Dettwyler examined the fairly consistent overall relationship between suckling duration and body weight for monkeys and apes.<sup>21</sup> The average value expected for a woman weighing about 120 pounds calculated from that relationship is close to three years.

- 19 Martin, R.D. 1990. *Primate Origins and Evolution: A Phylogenetic Reconstruction*. New Jersey: Princeton University Press; Martin, R.D. 2007. The evolution of human reproduction: A primatological perspective. *Yearbook of Physical Anthropology*, 135(45):59-84 [<https://doi.org/10.1002/ajpa.20734>]; Martin, R.D. 2013. *How We Do It: The Evolution and Future of Human Reproduction*. New York: Basic Books.
- 20 Van Noordwijk, M.A. & Van Schaik, C.P. 2005. Development of ecological competence in Sumatran orangutans. *American Journal of Physical Anthropology*, 127(1), May:79-94. [<https://doi.org/10.1002/ajpa.10426>].
- 21 Dettwyler, K.A. 1995. A time to wean: The hominid blueprint for a natural age of weaning in modern human populations. In: Stuart-Macadam, P. & Dettwyler, K.A. (eds). 1995. *Breastfeeding: Biocultural Perspectives*. New York: Aldine de Gruyter. 39-73.



There are also several other ways of estimating a natural duration for human breastfeeding by conducting comparisons of life-history milestones across primates. The underlying assumption here is that life-history patterns generally show coordination of individual phases, such that the overall tempo is either fast or slow. One simple approach is to start at the beginning of individual development and take the length of human pregnancy – the interval between conception and birth – to calculate expected weaning age from the duration of suckling in relation to gestation period in non-human primates. Dettwyler noted that the average duration of breastfeeding among large-bodied primates far exceeds the average length of gestation.<sup>22</sup> In our closest relatives – chimpanzees and gorillas – the duration of breastfeeding is more than six times the length of gestation. On that basis, she estimated that the natural age at weaning for humans would at least four-and-a-half years. Following birth, another important developmental milestone is the eruption of the first permanent molar teeth. Anthropologist Holly Smith has examined the relationship between the timing of dental eruption and age at weaning in primates and other mammals.<sup>23</sup> In primates, these events coincide closely in time. In modern humans, the first permanent molars erupt at about six years (range: 5.5 to 6.5).

Another rule of thumb can be derived from the weight the offspring reaches by the time of weaning. In a 1991 paper, Phyllis Lee and colleagues examined the attainment of a threshold body weight by weaning age in offspring of three groups of large-bodied mammals: higher primates, ungulates (hoofed mammals) and pinnipeds (seals and sea-lions).<sup>24</sup> It emerged that offspring in these mammals have approximately quadrupled their birth weight by the time they are weaned. Taking an average human birth weight of 3.5 kilograms (7.7 pounds), quadrupling it to 14 kilograms (31 pounds) would be expected to happen by an age close to three years in a well-nourished, healthy population and somewhere between three and four years of age in a population with marginal nourishment exposed to elevated environmental stress levels. The weaning age is also indicated by the age at which a child reaches a third of adult body weight. A 1993 paper by Eric Charnov and David Berrigan indicates that primates, on average, resemble other mammals in weaning

22 Dettwyler, K.A. 2004. When to wean: Biological versus cultural perspectives. *Clinical Obstetrics & Gynecology*, 47(3), September:712-723. [<https://doi.org/10.1097/01.grf.0000137217.97573.01>].

23 Smith, B.H. 1989. Dental development as a measure of life history in primates. *Evolution*, 43(3), May:683-688. [<https://doi.org/10.2307/2409073>]; Smith, B.H. 1992. Life history and the evolution of human maturation. *Evolutionary Anthropology*, 1(4), June:134-142. [<https://doi.org/10.1002/evan.1360010406>].

24 Lee, P.C., Majluf, P. & Gordon, I.J. 1991. Growth, weaning and maternal investment from a comparative perspective. *Journal of Zoology*, 225(1), March:99-114. [<https://doi.org/10.1111/j.1469-7998.1991.tb03804.x>].

an offspring when it reaches this stage of development.<sup>25</sup> Applying this criterion to humans yields a breastfeeding duration between four and seven years.

Last but not least, human weaning age can be inferred from the age at which sexual maturity is attained. In 1985, Paul Harvey and Timothy Clutton-Brock reported a close correlation between age at weaning and age at first breeding for female non-human primates.<sup>26</sup> Using the regression equation provided by Harvey and Clutton-Brock, Dettwyler calculated an expected average duration of human breastfeeding of 4.7 years taking an average female age at first reproduction of 16 years. If an average age at first reproduction of 12 years of age is taken instead, the estimated average duration of breastfeeding is 3.2 years. Accordingly, the shortest duration of breastfeeding predicted with this approach would be greater than three years.

An estimated natural human breastfeeding period of about three years may seem surprisingly long. It is actually on the short side compared to our closest relatives among primates, the great apes (chimpanzees and bonobos, gorillas, orangutans). The difference in body size between humans and great ape species is far less than across primates generally, so a direct comparison of lactation periods is reasonably informative in this case. Three months is in fact below the averages for all wild-living great apes: four-and-a-half years for common chimpanzees and bonobos, three-and-a-half years for gorillas, and six-and-a-half to seven years for orangutans.<sup>27</sup> Moreover, adult female chimpanzees weigh in at about ninety pounds, markedly less than the average woman. So, weaning in chimpanzees should be expected to occur *earlier* than in humans, not *later*. Because of an additional grade shift in the scaling relationship between weaning age and mother's body mass, apes tend to have somewhat later weaning ages, relative to body size, than monkeys. Because of this further difference, the natural suckling duration of three years inferred for humans from an examination of monkeys and apes together may be too low.

It is, however, possible that comparative evidence from non-human primates might not be entirely reliable. Following divergence of the sister lineages leading to humans and chimpanzees and bonobos, a special adaptation leading to a

25 Charnov, E.L. & Berrigan, D. 1993. Why do female primates have such long lifespans and so few babies? or life in the slow lane. *Evolutionary Anthropology*, 1(6), June:191-194. [<https://doi.org/10.1002/evan.1360010604>].

26 Harvey, P.H. & Clutton-Brock, T.H. 1985. Life history variation in primates. *Evolution*, 39(3), May:559-581. [<https://doi.org/10.1111/j.1558-5646.1985.tb00395.x>].

27 Van Noordwijk, M.A., Willems, E.P., Atmoko, S.S.U. & Van Schaik, C.P. 2013. Multi-year lactation and its consequences in Bornean orangutans (*Pongo pygmaeus wurmbii*). *Behavioral Ecology & Sociobiology*, 67(5):805-814. [<https://doi.org/10.1007/s00265-013-1504-y>].

*reduction* in the duration of human breastfeeding could have occurred. For instance, adaptation for a nutrient-rich, high-energy diet throughout human evolution could have allowed supplementary feeding of babies at an early stage of lactation, may be facilitated by the participation of social group members other than mothers in the rearing of infants and children. Various authors have proposed that this might have allowed earlier weaning. In a 2003 paper, anthropologist Gail Kennedy specifically argued that the high energy demands of the development of the particularly large human brain and a need for more rapid reproduction could have led to a ‘weanling’s dilemma’.<sup>28</sup> It has since been widely accepted among anthropologists that humans are, indeed, specially adapted for earlier weaning than in great apes.

To probe deeper into this question, we can conduct a comparative survey of information for our species. One clue to the natural lactation period for humans is provided by the age at which the production of lactase (a specific enzyme for the breakdown of lactose) stops in populations that are not biologically adapted for digestion of dairy products after weaning. In most human populations, the gene for production of lactase is switched off in children when they reach an age of about five years. Unfortunately, the timing of this is too variable to provide more than a hint of the natural duration of lactation, but it does indicate a relatively late weaning age. However, social norms and individual preferences governing weaning practices differ widely between human societies and also change over time. Current practices range from nursing for up to six years or more to not breastfeeding at all, resorting either to bottle-feeding or to using wet nurses.

One comparative approach is to examine information concerning modern human societies with a hunting-and-gathering lifestyle, possibly yielding an indication of average weaning age under conditions closer to those that prevailed for some 97 per cent of human evolution along the seven-million-year lineage leading from the earliest hominids to modern *Homo sapiens*. Because genuine hunting-and-gathering societies generally lack domesticated mammals as an alternative milk source, cultural practices have considerably less impact on weaning age. We should not, however, forget that the early introduction of supplementary feeding in infant rearing can influence the duration of breastfeeding in all contemporary human societies.

It turns out that breastfeeding generally lasts an average of three years in existing gathering-and-hunting societies. In a widely influential paper published in 1980, anthropologists Melvin Konner and Carol Worthman reported weaning of children at an average age of three-and-a-half years among the !Kung-gatherer-hunters

28 Kennedy, G.E. 2005. From the ape’s dilemma to the weanling’s dilemma: early weaning and its evolutionary context. *Journal of Human Evolution*, 48(2), February:123-145. [<https://doi.org/10.1016/j.jhevol.2004.09.005>].

of Botswana and Namibia.<sup>29</sup> This pioneering two-year study became a textbook example of fieldwork in human biology. Twenty-five years later, Konner published a chapter in a book on gatherer-hunters in which he reviewed information on weaning in five different societies.<sup>30</sup> In addition to the !Kung, he included information on the Agta, Hadza, Aka, and Ache, with the Aka's average weaning age three-and-a-half years as with the !Kung. Weaning occurred earlier in the other gathering-hunting societies, at around two years in the Agta and Ache and two-and-a-half years in the Hadza. The average weaning age across all five societies was close to three years (33.2 months).

Spreading the net more widely, Daniel Sellen, an anthropologist who has devoted his career to exploring the evolutionary background to human mothering, conducted a general survey of weaning age in 112 non-industrialised societies. His results, published in 2001, revealed that the extended duration of breastfeeding reported for gatherer-hunters is generally typical in a non-industrialised context.<sup>31</sup> In his sample, weaning occurred at an average age of about two-and-a-half years (29 months). However, there was considerable variation, with an overall range between one year and five-and-a-half years.

Overall, the balance of evidence, both from non-human primates and from human gathering-and-hunting societies, indicates that a natural weaning age in humans would be *at least* three years. Although many authors have concluded that the weaning age was reduced after humans diverged from great apes, they nevertheless maintained a basic pattern of relatively late weaning that is still evident in modern gatherers-and-hunters living close to nature. A weaning age of three years is less than in extant great apes, but it is still considerably longer than the average condition seen in most societies today. Moreover, the proposal that weaning age was reduced during human evolution is not entirely convincing. As a rule, in mammals, *all* life-history phases evolve in tandem, such that late attainment of sexual maturity and a lengthy lifespan are usually accompanied by a delayed age of weaning. So a reduction in the human age weaning conflicts with our very slow sexual maturation and our unusually long lifespan. The hypothesis that natural selection favoured increased reproductive output in early humans also clashes with the expectation

29 Konner, M.J. & Worthman, C. 1980. Nursing frequency, gonadal function, and birth spacing among !Kung hunter-gatherers. *Science*, 207(4432), February:788-791. [https://doi.org/10.1126/science.7352291].

30 Konner, M. 2005. Hunter-gatherer infancy and childhood: The !Kung and others. In: Hewlett, B.S. (ed). *Hunter-Gatherer Childhoods: Evolutionary, Developmental, and Cultural Perspectives*. New York: Routledge. 19-64.

31 Sellen, D.W. 2001. Comparison of infant feeding patterns reported for nonindustrial populations with current recommendations. *Journal of Nutrition*, 131(10), October:2707-2715. [https://doi.org/10.1093/jn/131.10.2707].

from our general life-history pattern. As Dettwyler has rightly emphasised, the natural (i.e. ancestral) period of breastfeeding in the human species is *at least* three years and may well be substantially longer.<sup>32</sup>

A natural weaning age of at least three years might come as a shock to women who are accustomed to nursing their babies for three to six months, with a maximum of a year. It is therefore important to emphasise that the figure of three years is for *total duration* of breastfeeding. Cross-cultural research by Daniel Sellen and others indicates that exclusive breastfeeding usually lasts six months to a year. For the rest of the time until weaning the infant receives supplementary foods in addition to breast milk. In 2005, the Section on Breastfeeding of the American Academy of Pediatrics recommended that, wherever possible, an infant should be exclusively breastfed for six months and weaned at a year. Both the World Health Organization (WHO) and the United Nations Children's Fund have also advocated six months of exclusive breastfeeding but now recommend weaning at two years. So we are inching our way back to the timing that biological and anthropological comparisons suggest.

We can also obtain information about weaning age by looking back into the distant past. For instance, documentary sources for the Pharaonic period in Egypt (between 2686 and 332 BC) indicate that infants were breastfed up to an age of three years. Already at that time, older infants were sometimes given milk from domestic mammals as a supplement.

Fortunately, our information sources are not limited to written documents. It is possible to gain useful information from chemical analyses of bones excavated at archaeological sites by measuring isotopes (variants of a chemical element that have the same number of protons in each atom but differ in the number of neutrons). It has been known for some time that isotope ratios for certain elements, notably nitrogen and carbon, change in a consistent fashion from the bottom to the top of the food chain. When herbivores eat plants, certain isotopes are enriched, and that enrichment process is carried further when predators eat herbivores. Consequently, the greatest degree of enrichment is found in predators at the top of the food chain. Ironically, the same thing happens when mothers suckle babies. Perhaps not surprisingly, isotopes in milk are enriched in suckled infants just as if they were predators feeding on the mother's body. The nitrogen isotope <sup>15</sup>N and the carbon isotope <sup>13</sup>C are both enriched relative to maternal levels in an infant's body (including the skeleton) during breastfeeding and then return to baseline after weaning.<sup>33</sup>

32 Dettwyler, 2004.

33 Carlson, 1999; Rodgers, 1978.

Analysing stable isotopes in skeletons of all ages, anthropologist Tosha Dupras and colleagues investigated infant feeding and weaning practices during the Roman period some 2 000 years ago at the Dakhleh Oasis in Egypt.<sup>34</sup> The study revealed that Egyptian mothers at this site probably introduced supplementary foods when their infants were around six months of age and completed weaning by three years of age. Investigation of isotopes in animal and plant remains from an ancient village nearby yielded valuable additional information. After the age of about six months, infants were fed with milk from goats or cows.

Even earlier evidence is available from studies of nitrogen isotopes in skeletons of infants and children from two Neolithic sites in Anatolia, Turkey, dating back around 10 000 years. Archaeologist Jessica Pearson and colleagues used isotope analysis to glean clues about foods eaten by past populations and the relationship between diet and health.<sup>35</sup> They also studied skeletons from archaeological sites to seek features that indicate past activities. The team reported that, in their study populations, exclusive breastfeeding lasted one to two years and weaning occurred between two and three years after birth. Both Anatolian communities were on the cusp of the shift from gathering and hunting to agriculture, harvesting a few domesticated plants and living with some not-yet-domesticated animals.

So comparative evidence from primatology, anthropology and archaeology uniformly indicates that our gathering-and-hunting ancestors 10 000 years ago would have breastfed babies for *at least* three years. Accordingly, in assessing the natural advantages and benefits of breastfeeding, it is biologically appropriate to compare bottle-fed infants with children that have been breastfed for three years or more. It is certainly barely informative to use the category 'ever breastfed' for comparison with bottle-fed infants.

In fact, in 1999, Anderson and colleagues reported another significant finding from their meta-analysis of 20 individual studies: Benefits for mental development increased with the duration of breastfeeding.<sup>36</sup> So, nursing for three years rather than just a few months can be confidently expected yield greater benefits. In 1993, developmental biologists Walter Rogan and Beth Gladen threw valuable light

34 Dupras, T.L., Schwarcz, H.P. & Fairgrieve, S.I. 2001. Infant feeding and weaning practices in Roman Egypt. *American Journal of Physical Anthropology*, 115(3), July:204-212. [<https://doi.org/10.1002/ajpa.1075>].

35 Pearson, J.A., Hedges, R.E.M., Molleson, T.I. & Özbek, M. 2010. Exploring the relationship between weaning and infant mortality: An isotope case study from Asikli Höyük and Cayönü Tepesi. *American Journal of Physical Anthropology*, 143(3), November:448-457. [<https://doi.org/10.1002/ajpa.21335>].

36 Anderson et al., 1999.



on this possibility.<sup>37</sup> In a well-designed prospective study, they tested some 800 children aged between six months and five years. Their results confirmed the oft-reported finding that average scores are significantly higher in breastfed than bottle-fed children, albeit by only a few points. More interestingly, however, they showed that scores mounted continuously as the duration of breastfeeding increased, from a few weeks to over a year.

Another, notably more recent, prospective study published in 2015 by Vasiliki Leventakou and colleagues analysed data for 540 mother-child pairs included in a cohort study in Heraklion, Crete in Greece, to examine the effect of breastfeeding duration.<sup>38</sup> The authors emphasised that few studies had addressed this issue. When children reached the age of 18 months, their cognitive, linguistic and motor development were assessed with standard tests (Bayley scales). Statistical procedures were applied to control an impressive range of potential confounding factors:

- ☐ maternal and paternal age at birth;
- ☐ the educational level at recruitment;
- ☐ Greek versus non-Greek origin;
- ☐ the mother's working status at the time of testing;
- ☐ marital status at birth;
- ☐ maternal and paternal smoking during pregnancy;
- ☐ parents' relationship when the child was aged nine months;
- ☐ postpartum depressive symptoms assessed at eight to 10 weeks after delivery;
- ☐ the child's sex;
- ☐ type of delivery;
- ☐ siblings at birth;

37 Rogan, J.W. & Gladen, B.C. 1993. Breast feeding and cognitive development. *Early Human Development*, 31(3), January:181-193. [[https://doi.org/10.1016/0378-3782\(93\)90194-y](https://doi.org/10.1016/0378-3782(93)90194-y)].

38 Leventakou, J., Roumeliotaki, T., Koutra, K., Vassilaki, M., Mantzouranis, E., Bitsios, P., Kogevinas, M., Chatzi, L. 2015. Breastfeeding duration and cognitive, language and motor development at 18 months of age: Rhea mother-child cohort in Crete, Greece. *Journal of Epidemiology and Community Health*, 69(3), March:232-239. [<https://doi.org/10.1136/jech-2013-202500>].

- ☐ birth order;
- ☐ birth weight;
- ☐ head circumference;
- ☐ body length;
- ☐ gestational age;
- ☐ preterm birth;
- ☐ neonatal intensive care and hospitalization;
- ☐ daycare attendance at 18 months of age;
- ☐ daily time spent with mother and father at 18 months of age (hours); and
- ☐ age at which solid foods were introduced.

Even after allowing for possible effects of all of these factors, a positive effect of breastfeeding duration was found with test scores for all capacities except gross motor development, namely, cognitive development, receptive communication, and expressive communication. For every month of breastfeeding, scores increased by about 0.3 points. Unfortunately, the study did not distinguish breastfeeding duration beyond six months, but a simple linear continuation in the trend would result in an improvement of more than 10 points after three years.

Of course, the underlying assumption is that development of the brain directly benefits from breastfeeding. It is therefore pertinent to obtain information on actual brain development rather using the indirect method of assessing mental capacities. In 2013 Sean Deoni and colleagues published results from a novel approach using the non-invasive technique of magnetic resonance imaging to examine brain development in human infants.<sup>39</sup> These authors examined 133 healthy children aged between 10 months and four years to estimate the total amount of white matter, which consists of the myelin-sheathed nerve fibres that convey signals in the brain. It emerged that, at any given age, breastfed children consistently had more white matter in the later-maturing frontal and association regions of the brain. Deoni and colleagues also found a positive relationship between the duration of breastfeeding and the development of white matter in

39 Deoni, S.C.L., Dean, D.C., Piryatinsky, I., O'Muircheartaigh, J., Waskiewicz, N., Lehman, K., Han, M. & Dirks, H. 2013. Breastfeeding and early white matter development: A cross-sectional study. *NeuroImage*, 82, November:77-86. [<https://doi.org/10.1016/j.neuroimage.2013.05.090>].

several brain regions that could account for higher scores in scores for cognitive and behavioural performance. The authors concluded that their findings “support the hypothesis that breast milk constituents promote healthy neural growth and white matter development”.

## Additional benefits of breastfeeding

Thus far, the discussion has focused on the nutritional content of milk, but breast milk did not evolve exclusively to nourish babies. It has several additional benefits. For instance, a mammalian mother also provides her offspring with a cocktail of antibiotic ingredients in her milk. In particular, while her infant’s active defence mechanisms are developing, she temporarily provides passive protection against microbes. Such protection against infection may have been one of the earliest functions of suckling. Paediatrician Armond Goldman noted that the oily secretions of sebaceous glands (the likely precursors of mammary glands) in mammals contain immune factors similar to those present in milk.<sup>40</sup> In his 2000 paper reviewing several key features of human milk, nutritionist Bo Lönnerdal reported that these include various agents of immunity, such as antibodies and immune cells, and that most of the specific active ingredients are proteins.<sup>41</sup>

Beneficial bacteria also take up residence in the digestive tract. As babies are sterile at birth, however, they have to accumulate the bacteria they need from local sources, and the natural provider is the breastfeeding mother. Almost inevitably, harmless bacteria inhabiting the gut differ between breastfed and bottle-fed infants, although suitable supplements can be added to milk formula to overcome this problem. In his 1995 article, Jack Newman, a paediatrician who founded the influential breastfeeding clinic at the Hospital for Sick Children in Toronto, reviewed the protective agents against noxious microbes provided by human milk.<sup>42</sup> Newman noted that in several countries mothers directly use their breast milk to treat eye infections in infants. A child’s immune response does not reach full strength until it is about five years old, so the protection provided by breastfeeding is sorely needed. Doctors have long recognised that breastfed infants contract fewer infections and suffer less than bottle-fed infants from meningitis or infections of the gut, ear, respiratory system, and urinary tract. That difference applies even when infants are fed with milk formula that has been sterilised.

40 Goldman, A.S. 2002. Evolution of the mammary gland defense system and the ontogeny of the immune system. *Journal of Mammary Gland Biology & Neoplasia*, 7(3), July:277-289. [<https://doi.org/10.1023/a:1022852700266>].

41 Lönnerdal, 1995.

42 Newman, 1995.

All human babies receive some protection from their mothers even before birth. Antibodies pass across the placenta to the fetus during pregnancy, and they continue to circulate in the infant's blood for weeks or even months after birth. From birth onwards, breastfed infants receive extra protection from antibodies, other proteins, and immune cells in human milk. Some proteins bind to microbes inside the gut cavity, preventing them from passing through the gut wall. Others reduce the supply of certain minerals and vitamins that noxious bacteria need to survive in the gut. For instance, a special binding protein reduces the availability of vitamin B12, while lactoferrin captures iron. Bifidus factor actively promotes the growth of beneficial bacteria in the infant's gut.

In addition to the basic types of antibodies, human milk contains numerous immune cells, including some that attack microbes directly. The most abundant type of antibody in human milk is secretory Immunoglobulin A, which includes a component that shields it against digestion in the infant's gut. Until they begin producing their own secretory Immunoglobulin A, usually some weeks or months after birth, bottle-fed infants have only limited resources to protect them against noxious microbes. As Newman concluded: "Breast milk is truly a fascinating fluid that supplies infants with far more than nutrition. It protects them against infection until they can protect themselves."

Around the time of birth, human mothers produce a special kind of yellowish, low-fat milk known as *colostrum*, a widespread, probably universal feature of mammals. Its primary, vital function is to transfer immunity from mother to offspring immediately after birth. Immune cells and the antiviral agent interferon are concentrated in colostrum, which also includes growth factors that promote the development of the infant's digestive tract. It is hence particularly important for newborn baby mammals, including human infants, to receive the first batch of milk that the mother produces. Before the latter part of the 17th Century, European society did not recognise the significance of colostrum for the health of human babies. Previously, colostrum was widely believed to be harmful. This extraordinary view was seemingly widespread among preindustrial societies and persisted in medieval Europe. It dates back at least as far as claims made by the second-century Greek physician Soranus of Ephesus, offering a striking example of how cultural norms sometimes clash directly with biological reality.

It must also be mentioned that bottle-feeding may generally trigger allergic responses in susceptible individuals. Public health scientist Michael Burr and colleagues studied wheezing and allergy in almost 500 children with a family history of allergic complaints.<sup>43</sup> Wheezing occurred in just over half of children

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43 Burr, M.L., Limb, E.S., Maguire, M.J., Amarah, L., Eldridge, B.A., Layzell, J.C. &

that had ever been breastfed, whereas it affected three-quarters of exclusively bottle-fed children. The difference persisted even after allowing for several possible confounding factors. Burr and colleagues concluded that breastfeeding may confer long-term protection against respiratory infection – yet another example of the benefits of natural nursing.

## Benefits of breastfeeding for mothers

It is now widely accepted that breastfeeding an infant has advantages over bottle-feeding, notably concerning brain development. However, it has been far less widely reported that breastfeeding also has genuine benefits for the well-being of the mother. These range from faster recovery of the womb after birth through a reduced risk of cardiovascular disease and on to a decreased risk for certain cancers later in life.

Immediate breastfeeding after birth helps to reduce blood loss by increasing the frequency of uterine contractions. While breastfeeding an infant during the first few days after birth, women commonly experience after-pains in the womb. Taking this experience as a starting-point, Selina Chua and her colleagues studied a small sample of 11 women, who served as their own controls. Following an uncomplicated birth in all cases, the effects of breastfeeding and nipple stimulation on womb activity were compared to baseline levels.<sup>44</sup> Chua and her colleagues found that the tempo of uterine contractions almost doubled during breastfeeding. The rate of contraction was also boosted with nipple stimulation alone, although not to the same extent.

Breastfeeding is generally associated with faster recovery of the womb after birth and helps to restore the mother's general physical condition. This finding has important practical consequences because haemorrhage after birth is a major cause of maternal death in Third World countries.<sup>45</sup> In 1993, for World Breastfeeding Week the WHO sent out a press release stating that, in the absence of suitable medical facilities, breastfeeding or nipple stimulation may be a safe, effective and

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Merrett, T.G. 1993. Infant feeding, wheezing, and allergy: a prospective study. *Archives of Diseases in Childhood*, 68(6), June:724-728. [<https://doi.org/10.1136/adc.68.6.724>].

- 44 Chua, S., Arulkumaran, S., Lim, I., Selamat, N. & Ratnam, S.S. 1994. Influence of breastfeeding and nipple stimulation on postpartum uterine activity. *British Journal of Obstetrics & Gynaecology*, 101(9), September:804-805. [<https://doi.org/10.1111/j.1471-0528.1994.tb11950.x>].

- 45 Abrams, E.T. & Rutherford, J.N. 2011. Framing postpartum hemorrhage as a consequence of human placental biology: An evolutionary and comparative perspective. *American Anthropologist*, 113(3):417-430. [<https://doi.org/10.1111/j.1548-1433.2011.01351.x>].

economical means of reducing blood loss after birth. This advice applied especially to blood loss resulting from significant bleeding during the third stage of labour.

Heart disease is the leading cause of death in women in the USA. It is therefore of some importance that, over the long term, breastfeeding reportedly reduces the risk that mothers will eventually suffer from blockages in the circulatory system notably in the arteries of the heart (cardiovascular disease). In 2009, Eleanor Schwarz and colleagues published their results from an investigation of almost 140 000 postmenopausal women with a median age of 63 years who reported having at least one live birth.<sup>46</sup> The women concerned had either enrolled for observational study within the Women's Health Initiative or were included in controlled trials. To examine the relationship between risk factors for cardiovascular disease and duration of breastfeeding, Schwarz and colleagues applied multivariate models that allowed for effects of a variety of possible confounding factors, including age, parity, ethnicity, education, income, age at menopause, lifestyle and family history variables. Data for obesity, hypertension (high blood pressure), self-reported diabetes, high blood fat (notably cholesterol and triglycerides) and cardiovascular disease were analysed. Compared to women who had never breastfed, it emerged that those reporting a lifetime total of more than 12 months lactation were significantly less likely to have four of those conditions, although they were not less likely to be obese. Schwarz and colleagues estimated that, among women who had given birth, those who did not breastfeed compared with those who breastfed for more than 12 months were more likely to have hypertension (42.1 per cent versus 38.6 per cent), diabetes (5.3 per cent versus 4.3 per cent), high blood fat (14.8 per cent versus 12.3 per cent) and cardiovascular disease appearing after menopause (9.9 per cent versus 9.1 per cent).

In 2015, a team led by Erica Gunderson reported on a similar study of breastfeeding concerning hardening of the arteries (atherosclerosis), which is the main cause of heart attacks, stroke, and peripheral vascular disease.<sup>47</sup> They examined data from a multi-centre prospective study in the USA titled, *Coronary Artery Risk Development in Young Adults*. In that study, women were initially examined for a baseline evaluation in 1985-1986 when aged 18-30 years and then re-examined

46 Schwarz, E.B., Ray, R.M., Stuebe, A.M., Allison, M.A., Ness, R.B., Freiberg, M.S. & Cauley, J.A. 2009. Duration of lactation and risk factors for maternal cardiovascular disease. *Obstetrics & Gynecology*, 113(5), May:974-982. [<https://doi.org/10.1097/01.AOG.0000346884.67796.ca>].

47 Gunderson, E.P., Quesenberry, C.P., Ning, X., Jacobs, D.R., Gross, M., Goff, D.C., Pletcher, M.J. & Lewis, C.E. 2015. Lactation duration and midlife atherosclerosis. *Obstetrics & Gynecology*, 126(2), August:381-390. [<https://doi.org/10.1097/AOG.0000000000000919>].



20 years later in 2005-2006. Gunderson and colleagues selected 846 women who had no heart disease or diabetes at baseline and subsequently had one or more births. For each woman, the total duration of breastfeeding was calculated across all births after baseline examination and allocated to one of the following categories: zero to less than one month; one to six months; six to 10 months; 10 months or more. Atherosclerosis was assessed by using ultrasound to measure the thickness of the innermost two layers of the wall of the common carotid artery. Statistical methods were applied to exclude confounding effects of pre-pregnancy obesity, cardiometabolic status, parity and other risk factors in comparisons between breastfeeding categories. Carotid wall thickness was found to have an inverse relationship with duration of breastfeeding that remained significant after exclusion of confounding effects.

Health benefits of breastfeeding for the mother extend far beyond a lower incidence of heart disease. Epidemiological evidence indicates that the benefits include protection against certain cancers, notably breast cancer. One early pointer to this came from records of mammals kept in zoos, indicating that mammary cancers were more likely to develop in females that had never suckled offspring. Reports from the 1920s reinforced this possibility and suggested that human breasts that had never been used to feed an infant were more likely to become cancerous. In one ingenious approach to this question, in a 1977 paper, Roy Ing and colleagues examined the unusual case of women inhabiting fishing villages in Hong Kong, who customarily suckled infants only from the right breast.<sup>48</sup> Radiotherapeutic records for the period 1958-1975 were searched, and breast cancer patients were interviewed to compile details of their lactation history. For the sample as a whole, there was no difference between frequencies of cancers on the left and right sides. Comparisons of postmenopausal patients who had nursed exclusively from one breast with those who had never given birth or had given birth but had not breastfed, however, revealed a highly significant increase in the risk of cancer for the unsuckled breast. However, the paper by Ing and colleagues met with considerable criticism at the time because of perceived shortcomings.

The topic then remained dormant for over a decade until 1989, when Peter Layde and colleagues published a paper examining the relationship between age at first full-term pregnancy, number of births, duration of breastfeeding and the risk of breast cancer.<sup>49</sup> By that time, it was widely accepted that a woman's reproductive

48 Ing, R., Ho, J.H.C. & Petrakis, N.L. 1977. Unilateral breast-feeding and breast cancer. *Lancet*, 2(8029), July:124-127. [[https://doi.org/10.1016/s0140-6736\(77\)90131-3](https://doi.org/10.1016/s0140-6736(77)90131-3)].

49 Layde, P.M., Webster, L.A., Baughman, A.L., Wingo, P.A., Rubin, G.L. & Ory, H.W. 1989. The independent associations of parity, age at first full term pregnancy, and duration of breastfeeding with the risk of breast cancer. *Journal of Clinical Epidemiology*,

history exerts a strong influence on her risk of breast cancer, but the relationships between the individual factors involved remained unclear. The analysis was complicated by the fact that pregnancy itself is known to provide some degree of protection against breast cancer. To assess the respective contributions of different factors, Layde and colleagues used appropriate statistical techniques to analyze data from the *Cancer and Steroid Hormone Study*, a multi-centre case-control investigation. Four thousand and five hundred and ninety-nine women, identified as having an initial diagnosis of breast cancer, were compared with 4 536 randomly selected women from the same regions, serving as controls. In line with previous reports, age at first full-term pregnancy was found to exert a strong influence on breast cancer risk. However, after allowing for this influence along with the effects of several other potential confounding factors, it emerged that the number of births (parity) and duration of breastfeeding also made strong contributions to reducing the risk of breast cancer. Compared with women who had given birth only once, women who had had seven or more births showed a reduction of about 40 per cent in breast cancer risk. Similarly, compared with women who had given birth but never breastfed, women who had breastfed for a combined total exceeding two years showed a reduction of about 33 per cent.

Those findings were reinforced in a large-scale, worldwide review of available information published in 2002 by the Collaborative Group on Hormonal Factors in Breast Cancer.<sup>50</sup> The study examined information from 47 epidemiological studies in 30 countries, covering over 50 000 women with invasive breast cancer and almost twice as many who were cancer-free. The Collaborative Group's review confirmed the protective effects of pregnancy by showing that women with breast cancer had 15 per cent fewer births, with an average of 2.2 compared to 2.6. It also revealed that, among women who had given birth, just over 70 per cent of those who developed cancer had ever breastfed. By contrast, almost 80 per cent of women who remained cancer-free had breastfed to some extent. A further difference was detected for the average lifetime duration of breastfeeding. On average, women who developed cancer breastfed for only 9.8 months altogether, compared with a lifetime total of 15.6 months for women who remained cancer-free. The most important finding reported by the Collaborative Group was that the relative risk of breast cancer decreased by seven per cent for every birth and by more than four

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42(10):963-973. [[https://doi.org/10.1016/0895-4356\(89\)90161-3](https://doi.org/10.1016/0895-4356(89)90161-3)].

50 Collaborative Group on Hormonal Factors in Breast Cancer. 2002. Breast cancer and breastfeeding: collaborative reanalysis of individual data from 47 epidemiological studies in 30 countries, including 50 302 women with breast cancer and 96 973 women without the disease. 2002. *Lancet*, 360(9328), July:187-95. [[https://doi.org/10.1016/S0140-6736\(02\)09454-0](https://doi.org/10.1016/S0140-6736(02)09454-0)].

per cent for every year of breastfeeding. Combining all findings to estimate the cumulative incidence of breast cancer up to age 70 for developed countries, yielded the following conclusion:

If all women had the average number of births and lifetime duration of breastfeeding that characterized third world countries until recently, deaths from breast cancer could be more than halved – from one in 16 to one in 37 – the influence of breastfeeding accounts for almost two-thirds of this projected reduction.<sup>51</sup>

Breastfeeding has also been linked to a reduced risk of ovarian cancer. In the 1970s indications emerged that associated the absence of ovulation with a lower incidence of cancer of the ovaries. One notable development was a 1979 paper by John Casagrande and colleagues, who conducted a case-control study comparing 150 ovarian cancer patients under the age of 50 with individually matched controls. The aim was to assess the potential effects of fertility and oral contraceptives on ovarian cancer risk. Casagrande and colleagues found that a decreased risk was associated with increasing numbers of live births and incomplete pregnancies and also with the use of oral contraceptives. All three factors were regarded as periods free of ovulation and amalgamated into a single index termed, 'protected time'. The residual period after subtraction of protected time from the period between menarche and diagnosis of ovarian cancer (or cessation of menses), was strongly related to ovarian cancer risk. This study did not specifically address breastfeeding, but a connection with reduced risk of ovarian cancer seems likely because of the influence of numbers of live births and the long-recognized fact that ovulation is suppressed during full-time breastfeeding.

In 1993, Kerin Rosenblatt and David Thomas published results from a direct study of the relationship between breastfeeding and the risk of ovarian cancer with data derived from a WHO multinational study of associations between cancer and steroid contraceptives in 1979-1988.<sup>52</sup> Rosenblatt and Thomas compared 393 cases of ovarian cancer with 2 565 carefully matched controls. The risk of ovarian cancer was reduced by about a quarter in women who breastfed for at least two months, although this result did not reach statistical significance. No additional reduction in risk was found with longer-term lactation. Moreover, the reduction in risk associated with months of lactation was not as great as the reduction observed with months of pregnancy. Still, it is encouraging to note that breastfeeding for just

51 Collaborative Group on Hormonal Factors in Breast Cancer, 2002.

52 Casagrande, J.T., Pike, M.C., Ross, R.K., Louie, E.W., Roy, S., Henderson, B.E. 1979. 'Incessant ovulation' and ovarian cancer. *Lancet*, 2(8135), July:170-173. [[https://doi.org/10.1016/s0140-6736\(79\)91435-1](https://doi.org/10.1016/s0140-6736(79)91435-1)].

a few months after birth did seemingly provide some degree of protection against ovarian cancer.

A very useful overview of the beneficial effects of breastfeeding for the mother was provided by Miriam Labbok in 2001.<sup>53</sup> She stated:

... a clear pattern of positive physiologic changes that lead to improved short-term and long-term health sequelae is emerging. All patients and their families should be informed fully as to the positive preventive health effects of breastfeeding not only for infants but also for mothers. Women have many difficult choices to make; it behooves physicians to ensure that they receive all of the facts on which to base these decisions.

Labbok discussed ovarian cancer risk, referring to the 1979 paper by Casagrande and colleagues and their hypothesis that ‘incessant ovulation’ is a causal factor. She also mentioned several other studies, including one by Harvey Risch and colleagues, published in 1983, that reported a moderate reduction in the risk of ovarian cancer from interviews with patients and a random sample of women living in the same areas in Washington and Utah.<sup>54</sup> Logistic regression methods were applied, allowing for a range of potential confounding factors. Significant estimated relative risks of 0.88 per pregnancy, 0.82 per miscarriage, 0.79 per year of breastfeeding and 0.89 per year of oral contraception were determined. These diminished risks’ magnitude greatly exceeded those expected solely based on the inhibition of ovulation. Taking into account the 1993 study by Kerin Rosenblatt and David Thomas, Labbok concluded that that breastfeeding for two to seven months after birth is associated with a significant decrease in the risk of ovarian cancer, at a level averaging 20 per cent.<sup>55</sup> However, available data did not support a dose-response relationship with increased duration of breastfeeding, so some alternative explanation to that proposed by Casagrande and colleagues is seemingly needed.

A more recent case-control study by Dada Su and colleagues, published in 2013, referred to growing evidence indicating a protective effect of breastfeeding on the

53 Labbok, M.H. 2001. Effects of breastfeeding on the mother [review]. *Pediatric Clinics of North America*, 48(1), February:143-158.  
[https://doi.org/10.1016/s0031-3955(05)70290-x].

54 Risch, H.A., Weiss, N.S., Lyon, J.L., Daling, J.R. & Liff, J.M. 1983. Events of reproductive life and the incidence of epithelial ovarian cancer. *American Journal of Epidemiology*, 117(2), February:128-139.  
[https://doi.org/10.1093/oxfordjournals.aje.a113523].

55 Rosenblatt, K.A. & Thomas, D.B. 1993. Lactation and the risk of epithelial ovarian cancer. The WHO Collaborative Study of Neoplasia and Steroid Contraceptives. *International Journal of Epidemiology*, 22(2), April:192-197.  
[https://doi.org/10.1093/ije/22.2.192].

risk of ovarian cancer.<sup>56</sup> Their study, conducted in southern China in 2006-2008, used a questionnaire to obtain information on the number of children breastfed and total months of lactation for 493 ovarian cancer patients and 472 hospital-based controls. Logistic regressions were performed to assess the association between breastfeeding and the risk of ovarian cancer. Other independent variables included in the models as potential confounders were age at interview, parity, oral contraceptive use, ovarian or breast cancer in a first-degree relative, educational level, menopausal status, alcohol consumption, and smoking status. After allowing for these factors, significant inverse dose-response relationships were found for both the number of children breastfed and the total duration of lactation. Women with a total lactation greater than 31 months had only a tenth of the risk of ovarian cancer compared to women with less than ten months. Women who had breastfed more than three children had less than 40 per cent of the risk of ovarian cancer for women who had breastfed only one child.

## Opposition to campaigns to encourage breastfeeding

Accumulated evidence surely indicates that breastfeeding has distinct benefits for both mothers and infants. Although the evidence comes largely from epidemiological surveys and is therefore predominantly circumstantial, breastfeeding is associated with improved development of the infant's brain, reflected by higher scores on mental tests in breastfed children that are admittedly limited in scope but statistically significant. As far as mothers are concerned, breastfeeding heals the womb and wards off heart disease and protects against breast cancer. Various studies have indicated a dose-response relationship between duration of breastfeeding and health benefits for mothers and infants, vitally important because modern mothers living in industrialised societies very rarely breastfeed their infants for the minimum period of three years that has been inferred for early members of our species leading a gathering-hunting existence. As a result, many studies that have compared bottle-feeding with breastfeeding have analysed data from mothers who have commonly stopped nursing within a few months after birth, with a maximum of one year in rare cases. This behaviour may well explain why the differences between bottle-feeding and breastfeeding mothers have generally been quite small and why some studies have yielded inconclusive results. Indeed, studies that have used the category 'ever breastfed' in comparisons with bottle-feeding are virtually doomed from the outset. It is not at all reasonable to expect that babies that have been breastfed for less than a month after birth will

56 Su, D., Pasalich, M., Lee, A.H. & Binns, C.W. 2013. Ovarian cancer risk is reduced by prolonged lactation: a case-control study in southern China. *American Journal of Clinical Nutrition*, 97:354-359. [<https://doi.org/10.3945/ajcn.112.044719>].

show significant differences in brain development or associated scores of mental function. It is unreasonable to expect that mothers who have breastfed their infants for just a few weeks will show a significantly reduced risk of breast cancer.

Under ideal conditions, then, it would be in a woman's best interests – both for optimal development of her infant and for her well-being – to breastfeed her infant for at least three years. National and international agencies have progressively recognised this fact and have increasingly issued recommendations to encourage breastfeeding and to augment its duration. At the same time, however, it is important to acknowledge that, for medical and other reasons, many women are unable or unwilling to breastfeed, and campaigns that promote breastfeeding should avoid overt or implied criticism. Women who, for whatever reason, cannot breastfeed should certainly not be made to feel guilty.

So it should be made abundantly clear that the take-home message from this review of the natural history of breastfeeding is not that we all need to return to our gathering-and-hunting lifestyles, nor even that women should always try to breastfeed their babies. Instead, the appropriate message is that we should investigate in-depth the evolutionary background to human breastfeeding to ensure that any modifications resulting from current lifestyles fit all natural requirements as closely as possible. In particular, any formula provided as a substitute for breast milk should be optimised to provide everything that a baby needs. Moreover, we need to explore the benefits of breastfeeding for mothers in detail to develop treatments that will replicate the natural provided, especially relevant to devise ways of reducing risks of cancer to the level normally associated with several pregnancies and extended breastfeeding of the infants during a woman's lifetime.

We still have much to do, particularly in designing more appropriate milk formulae. Both women and babies are biologically adapted for at least three years of breastfeeding, so mothers who nurse their babies for just a few months are not much better off than mothers who do not nurse at all. Moreover, the general trend to reduced family size in industrialised nations is, in itself, diminishing the protective effect provided by pregnancies and extended breastfeeding of each infant. The simplest approach is for a woman to breastfeed every infant as long as possible, but what all mothers need and deserve is an appropriate formula to use whenever bottle-feeding is the only option.

The bottom line is that female mammals adapted not only for milk secretion and suckling but also for close mother-infant contact. In recent decades, health authorities have increasingly acted on evidence for natural advantages of breastfeeding by encouraging mothers to nurse babies as far as possible. Still, the widely used slogan, *Breast is Best*, has raised hackles in some quarters. Official



promotion of breastfeeding has not been universally welcomed and has triggered some quite strident opposition. One milestone was Hanna Rosin's 2009 article, *The case against breastfeeding*, in *The Atlantic*, feeding fairly directly on to the 2015 book, *Lactivism*, by Courtney Jung, Professor of Political Science at the University of Toronto.<sup>57</sup>

*Lactivism* has two main themes, one commendable and the other reprehensible. The first, praiseworthy, theme is that women who do not breastfeed – for whatever reason – should never be bullied. Many women try hard without success to nurse their babies, and they do not need over-zealous breastfeeding advocates to deepen their disappointment. Many other mothers cannot breastfeed for financial or medical reasons. The HI-virus is an oft-cited example, although it is unclear whether breastfeeding increases or decreases transmission risk. Regardless, slogans like *Breast is Best* are no excuse for demeaning women for not breastfeeding. What we need instead is scientifically-based replication of benefits when women cannot breastfeed.

Jung's second theme, though, is the systematic belittlement of the scientific evidence for benefits of breastfeeding, which are portrayed as minimal to non-existent. Enthusiastic advocates of breastfeeding do sometimes overstate benefits. Formula-reared babies fare remarkably well on an artificial substitute for human milk, especially because of manufacturers' feeble attempts to approximate human milk composition.

Jung's discussion of scientific findings though – essentially Chapter 3 of *Lactivism* – is patchy and selective. A key feature is her focus on paediatrician Michael Kramer as the prime source of expert opinion. It must be noted at once that Jung misrepresents his findings. Tom Bartlett sought comments from Kramer when reviewing *Lactivism* for *The Chronicle of Higher Education*. Kramer told him: "I think she chose to ignore some of the science ... I don't think it's a balanced summary of the evidence, and I do think it sends the wrong message."

The fundamental point here is that Kramer led the Promotion of Breastfeeding Intervention Trial (Probit, 1996-1997), described by Jung as "the largest and most authoritative study of the effects of breastfeeding to date".<sup>58</sup> Kramer was concerned

57 Rosin, H. 2009. The case against breast-feeding. *The Atlantic*, April issue. [<https://www.theatlantic.com/magazine/archive/2009/04/the-case-against-breast-feeding/307311/>]; Jung, C. 2015. *Lactivism: How Feminists and Fundamentalists, Hippies and Yuppies, and Physicians and Politicians Made Breastfeeding Big Business and Bad Policy*. New York: Basic Books.

58 Kramer, M.S., Chalmers, B., Hodnett, E.D. & Helsing, E. 2001. Promotion of Breastfeeding Intervention Trial (PROBIT): A randomized trial in the Republic of Belarus.

because previous studies that had provided evidence for breastfeeding benefits were largely observational with no possibility for testing, meaning that interpretations depended on correlations and their reliability depended on the degree to which effective exclusion of confounding factors could be achieved by statistical means. With great inspiration, Kramer designed a prospective procedure that would avoid ethical problems of actual experiments – taking 31 hospitals, half were randomly selected for specific promotion of breastfeeding (intervention group), while the other half continued existing practices (control group). For logistic reasons, the Republic of Belarus was chosen as the location for the project.

Over the past two decades, the Probit study has generated a steady flow of publications. Before it started, although most mothers initiated breastfeeding after birth, many introduced bottle-feeding soon afterwards and ceased breastfeeding entirely within three months. Strikingly, in the intervention group, exclusive breastfeeding of babies at three months of age proved to be more than seven times more likely than in the control group. Moreover, a year after birth, intervention mothers were twice as likely as control mothers to be still breastfeeding. It is vital to note, however, that the Probit study must necessarily *underestimate* breastfeeding benefits, because of its ingenious design to comply with ethical standards. The fundamental design of Probit does not permit comparison between breastfeeding and exclusive bottle-feeding; it only allows comparison of babies receiving a limited amount of breastfeeding with others whose mothers are encouraged to breastfeed for a longer period.

Encouragingly, despite its constraints, Probit neatly confirmed several findings from previous observational studies. The 2001 paper by Kramer and colleagues reported a significantly reduced risk of gastrointestinal tract infections (about a third lower) and atopic eczema (down by half) for intervention group babies.<sup>59</sup> On the other hand, respiratory tract infection showed no significant difference. Furthermore, various other Probit papers reported no significant positive effects of increased breastfeeding on height, weight, adiposity, Body Mass Index, blood pressure, diabetes, asthma or atopic eczema. For these conditions, confounding factors may have skewed previous observational studies. So, the spectrum of breastfeeding benefits may not be as broad as sometimes claimed.<sup>60</sup>

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*Journal of the American Medical Association*, 285(4), January:413-420.  
[<https://doi.org/10.1001/jama.285.4.413>].

59 Ibid.

60 Kramer, M.S., Matush, L., Vanilovich, I., Platt, R.W., Bogdanovich, N., Sevkovskaya, Z., Dzikovich, I., Shishko, G., Collet, J.P., Martin, R.M., Smith, G.D., Gillman, M.W., Chalmers, B., Hodnett, E. & Shapiro, S. 2007. Effects of prolonged and exclusive breastfeeding on child height, weight, adiposity, and blood pressure at age 6.5 y:

Another major breastfeeding benefit indicated by many other studies is protection against Sudden Infant Death Syndrome. Unfortunately, Probit yielded insufficient data for statistical tests of this widely accepted benefit. However, in 2011 Fern Hauck and colleagues published a meta-analysis of results from many previous studies that yielded convincing evidence of risk reduction.<sup>61</sup> Sudden infant death syndrome rates were lower with infants that received any breastfeeding at all and by almost three quarters with exclusive breastfeeding of any duration. These findings, incidentally, suggest that an extended period of breastfeeding may not be necessary to provide a significant degree of protection against sudden infant death syndrome. It also indicates that the Probit investigation would not have provided an adequate test of protection against sudden infant death syndrome, because infants in that study were generally breastfed to some extent.

Importantly, a 2008 paper by Kramer and colleagues from the Probit study reported that, when assessed with various intelligence tests at six-and-a-half years of age, intervention group children scored significantly higher – by up to 7.5 points (depending on test type) – than control group children.<sup>62</sup> Teachers' academic ratings for both reading and writing were also significantly higher. The team concluded: "These results, based on the largest randomized trial ever conducted in the area of human lactation, provide strong evidence that prolonged and exclusive breastfeeding improves children's cognitive development."

The core weakness of *Lactivism* is that Jung fails to mention evolution and indeed ignores biology almost completely.<sup>63</sup> This omission is encapsulated in her sweeping

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evidence from a large randomized trial. *American Journal of Clinical Nutrition*, 86(6), December:1717-1721. [<https://doi.org/10.1093/ajcn/86.5.1717>]; Patel, R., Oken, E., Bogdanovich, N., Matush, L., Sevkovskaya, Z., Chalmers, B., Hodnett, E.D., Vilchuck, K., Kramer, M.S. & Martin, R.M. 2014. Cohort profile: The Promotion of Breastfeeding Intervention Trial (PROBIT). *International Journal of Epidemiology*, 43(3), June:679-690. [<https://doi.org/10.1093/ije/dyt003>].

- 61 Hauck, F.R., Thompson, J.M.D., Tanabe, K.O., Moon, R.Y. & Vennemann, M.M. 2011. Breastfeeding and reduced risk of Sudden Infant Death Syndrome: A meta-analysis. *Pediatrics*, 128(1), July:103-110. [<https://doi.org/10.1542/peds.2010-3000>].
- 62 Kramer, M.S., Aboud, F., Mironova, E., Vanilovich, I., Platt, R.W., Matush, L., Igumnov, S., Fombonne, E., Bogdanovich, N., Ducruet, T., Collet, J.P., Chalmers, B., Hodnett, E., Davidovsky, S., Skugarevsky, O., Trofimovich, O., Kozlova, L. & Shapiro, S. 2008. Promotion of Breastfeeding Intervention Trial (PROBIT) Study Group. Breastfeeding and child cognitive development: New evidence from a large randomized trial. *Archives of General Psychiatry*, 65(5), May:578-584. [<https://doi.org/10.1001/archpsyc.65.5.578>].
- 63 Bartlett, T. 2015. Has mother's milk gone sour? *The Chronicle of Higher Education*. [<https://www.chronicle.com/article/Has-Mother-s-Milk-Gone-Sour-/234060>].

statement that “there has never been a time when *all* women breastfed”, surely only referring to recent recorded history. Our species would have ceased to exist if, for a substantial evolutionary period, breastfeeding had been eliminated to the extent seen around the world today. Suckling is universal in mammals and has that 200-million-year evolutionary history behind it that cannot simply be ignored.

The fundamental issue is still this: Few people today breastfeed to the extent that prevailed for hundreds of thousands of years before our species domesticated milk-yielding mammals around ten millennia ago. Multiple lines of evidence indicate that our hunting-and-gathering ancestors breastfed babies for ‘at least’ three years, exclusively for the first six months or so and then combined with complementary feeding until weaning. Few mothers today come anywhere near that original pattern. As already noted, studies of ‘breastfeeding’ often fail to distinguish between ‘ever breastfed’ (perhaps for just a few days after birth) and breastfeeding for a year or more. We have only very limited information about breastfeeding lasting for three years or more. The few studies about the duration of breastfeeding have consistently reported accumulating beneficial increases over time for mothers and infants.

*Lactivism* rightly censures bullying of mothers who do not breastfeed. On the other hand, its seriously misleading disparagement of breastfeeding benefits is downright dangerous. It may reduce pressure to develop effective solutions for mothers who cannot breastfeed. Right now, the best advice to new mothers is that they should breastfeed if they can and for as long as possible. Benefits are not huge, but any mother surely wants her infant to have fewer early infections, to have a lower probability of cot death, and to grow up to be as smart as possible. She will surely prefer decreased risks of cancer of the breast and ovaries. However, if for any reason breastfeeding is not an option, every attempt should be made to replicate its benefits. For working mothers, breastpumping remains a useful (not necessarily easy) option, despite all the negative comments in *Lactivism*. If the formula has to be used, then it should be optimised. For instance, the jury is still out regarding a requirement for omega-3 and omega-6 fatty acids. However, they are known to be important for brain development, and human milk contains them, whereas cow’s milk does not. So, it is wise to opt for a formula that contains them. Any formula used should, in any case, be closely scrutinised to see how effectively it matches human milk. Over the long term, pressure should be applied to oblige formula manufacturers to work harder to maximize the resemblance to human milk.