The 'Anatomy' of Infant Sucking

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This paper aims to present a simple account of the mechanisms by which a baby removes milk from the breast, gleaned from past and current literature, to counter the tendency for inaccurate descriptions of the mechanics of infant sucking to be reproduced. The process is described by which milk is expressed from the lactiferous sinuses within the nipple and breast, by compression of the nipple against the palate by rhythmical pulsations of the surface of the tongue. Active in the process of milk transfer are the roles played by negative suction pressure by the infant, and positive ductal pressure due to action of the mother’s milk ejection reflex, which interact in making milk available for removal. The reflexes which the newborn possesses to aid feeding are described and suggestions offered as how best to utilise the reflexes in order to fix a baby successfully on the breast. The intention is that armed with an appropriate understanding of the underlying processes by which milk is transferred from mother to baby a midwife is best equipped to advise a mother regarding the correct technique for achieving trouble-free breast-feeding.

Introduction:
It is clear from recent lay and professional texts that there is much confusion as to the precise nature of infant sucking, in particular over both the dynamic changes in anatomy and the physiological mechanisms involved in the process by which the infant obtains milk from the breast.
Although the description in many of these texts is substantially correct, the accompanying illustrations often contain inaccuracies which may themselves lead to a misunderstanding of the anatomical mechanisms involved. An incomplete or imprecise knowledge of these mechanisms can be a hindrance to offering adequate advice to the breast-feeding mother.
This article tries to give a clear description of the processes involved in the infant sucking at the breast, and in the transfer of milk. A companion article, based upon this description, considers the theoretical basis of some common complications of breast-feeding, and offer some suggestions as to the possible causes of nipple lesions (Woolridge, 1986)
The description of the dynamic anatomy of *normal* sucking is drawn both from older and from more recent studies of infants feeding at the breast. Previous descriptions, derived from direct scientific observations, are impressive for their simplicity and logic, but they have not received the critical attention they deserve in practical guides to breast-feeding and the lactation literature generally.
The studies of Ardran, Kemp and Lind (1958 a and b), receive relatively little consideration in textbooks of infant feeding, despite being the most important analyses undertaken. In contrast, the description supplied by Applebaum (1970) has been the most influential, being widely cited, and the one from which illustrations are most frequently reproduced. Applebaum’s description, however, contains a number of statements which are inconsistent with the findings of Ardran *et al.,*(1958 b). Despite a flawed description of the mechanics of milk transfer Applebaum’s work has much to recommend it.
Earlier studies have since been substantiated by Smith *et al.* (1985), and by the observations on the dynamic relationships of sucking using ultrasound scanner techniques for imaging events in the baby’s mouth (Weber, Woolridge and Baum, 1986). The following is an attempt at an economical but complete description of the physical events taking place in the baby’s mouth during breast-feeding.

The mechanics of sucking:
The nipple, with surrounding and underlying breast tissue, is drawn out into a teat by suction created within the baby’s mouth. This ‘teat’ is about three times as long as the nipple at rest, and extends back as far as the junction between the hard and soft palates (Ardan *et al.*, 1958 b). At its base it is held between the upper gum and the tongue, which covers the lower gum. The lateral margins of the tongue cup around the teat forming a cental trough in which the nipple lies. Milk is expressed from the ampullae (widening of the ducts prior to their exit at the nipple surface, also called lacteal or lactiferous sinuses), and propelled towards the back of

the mouth by a posteriorly directed, roller-like peristaltic wave along the surface of the tongue (Ardan *et al.*, 1958 b). The sucking cycle is initiated by an upward curving of the anterior rim of the tongue, closely followed by pressure from the lower gum, caused by elevation of the lower jaw (this action may serve to trap a pool of milk in the nipple sinuses preventing its reverse flow back into the alveolar duct system). The wave of compression moves backwards progressively occluding the central furrow in which the teat lies, thereby expressing milk from the lactiferous sinuses (Gwynne-Evans, 1951). Compression by the tongue causes the nipple to be indented on its lower surface, and this indentation is preceded by an area of slight expansion (see Fig.1 [after Weber *et al.*, 1985]). A view in medial section, as provided by ultrasound, would give the impression that the nipple is distended as its tip. (the oft-cited 'cherry-on-a-stalk' analogy [Evens & MacKeith, 1954]), although it has also become broader at the point of compression. As the point of compression moves back past the end of the nipple, the teat becomes shorter and slightly tapered.
Tongue elevation continues beyond the tip of the nipple moving the milk bolus into the pharynx. If the volume of the milk taken is sufficient to trigger swallowing[1] the soft palate rises and closes off the nasal cavity. The larynx separating the trachea from the oesophagus moves up and forward to close the trachea. This is aided by a downward movement of the epiglottis, resulting from pressure from the rear portion of the tongue and the fluid bolus. The pharyngeal space is progressively reduced and ultimately obliterated propelling the milk bolus into the oesophagus (Logan & Bosma, 1967).
The larynx then returns to its normal position, closing off the oesophagus behind the swallowed milk, and leaving the upper airways patent. Meanwhile a fresh cycle of compression by the tongue has been initiated from its front margin. The complete process is typified by peristaltic expulsion of milk from the nipple to the back of the pharynx, and on into the oesophagus; pulsatile progress typical of the rest of the alimentary tract.
It should be remembered that sucking is a dynamic process, and that pictorial representations freeze in time brief moments of the cycle for scrutiny. Visualising antecedent and subsequent changes, and events away from the midline, help to complete a dynamic 3-dimentional picture.

Ramifications of description:
Two features of this description deserve closer inspection both as general qualities of normal sucking, and because their disturbance may be of relevance to the aetiology of sore nipples. The first is a descriptive feature, that normal sucking is essentially free from frictional movement. If sufficient breast tissue has been formed into a 'teat' then there should be little movement of this teat in and out of the baby's mouth, simply unidirectional exchange of milk into the baby's mouth. Friction from the tongue and gums against the skin of the breast should be minimal. This picture is very different from that which is commonly depicted, whereby the nipple is stripped by the tip of the tongue moving back along the underside of the nipple, and apparently creating friction along its entire length. Such a picture is not consistent with reports made by cineradiographic and ultrasound observation (Ardran *et al.*, 1958 b; Smith *et al.*, 1985; Weber *et al.*, 1951)
The second feature is that, as described above, the application of positive pressure on the nipple by the surface of the tongue is the primary force in evacuating milk from the nipples, and despatching it down the oesophagus. No such role is suggested for the negative pressure, which the baby clearly generates in his mouth, during the process of milk removal (Hytten, 1951).

The role of negative pressure:
The role of negative pressure has not been categorically determined, but the two most likely functions are (i) to retain the nipple and breast in position within the mouth (i.e. to counter the naturally retractile nature of this tissue), thus maintaining the 'teat' shape of the nipple and breast tissue; and (ii) to aid refilling of the nipple by milk from the ducts and sinuses entering it.

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[1] It is not clear what initiates swallowing whether it is a neurally elicited response due to specific sensory stimulation (tactile or chemical), or whether the fluid in the oral cavity has reached a specified volume, physically displacing the tip of the palate from its niche behind the epiglottis. Laitman *et al.* (1977), claim that in the human newborn, as in other mammals, this 'locking' mechanism ensures continuity of the larynx and nasopharynx, and swallowing causes only a momentary separation.

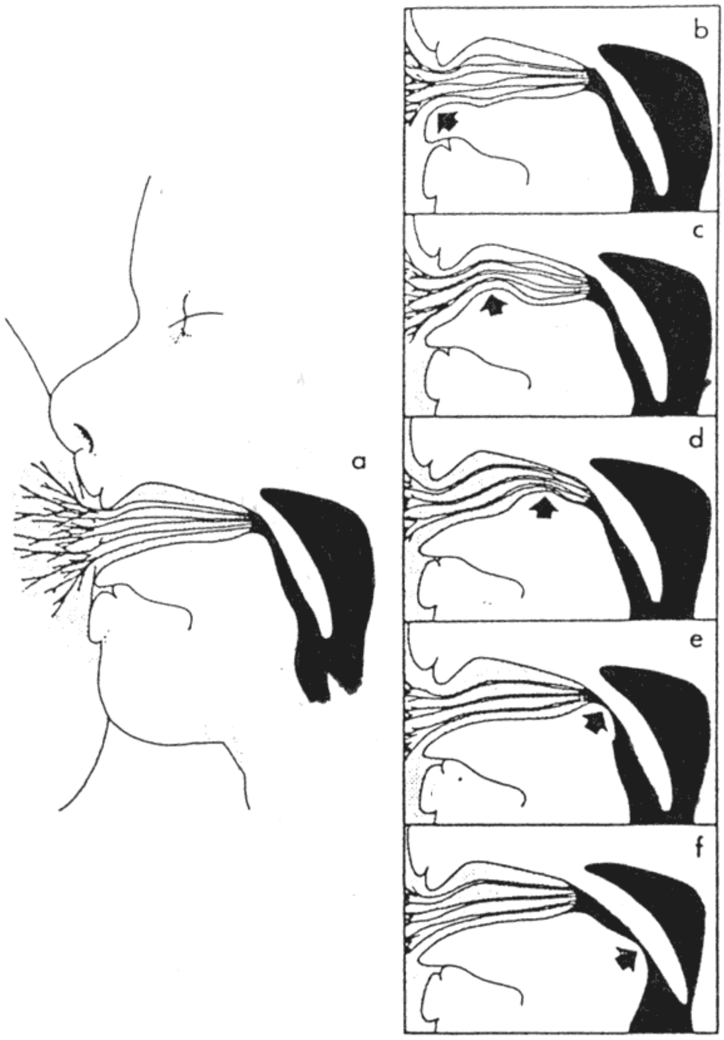

Fig. 1. Shows a complete 'suck' cycle; the baby is shown in median section. The baby exhibits good feeding technique with the nipple drawn well into the mouth, extending back to the junction of the hard and soft palate (the lactiferous sinuses are depicted within the teat though these cannot be visualised on scans).

a. 'Teat' is formed from the nipple and much of the areola, with the lacteal sinuses, which lie behind the nipple, being drawn into the mouth with the breast tissue. The soft palate is relaxed and the nasopharynx is open for breathing. The shape of the tongue at the back represents its position at rest, cupped around the tip of the nipple.

b. The suck cycle is initiated by a welling up of the anterior tip of the tongue. At the same time, the lower jaw, which had been momentarily relaxed (not shown), is raised to constrict the base of the nipple, thereby 'pinching off' milk within the ducts of the teat (these movements are inferred as they lie outside the sector viewed in ultrasound scans).

c. The wave of compression by the tongue, moves along the underside of the nipple in a posterior direction, pushing against the hard palate. This roller-like action squeezes milk from the nipple. The posterior portion of the tongue may be depressed as milk collects in the oropharynx.

d. & e. The wave of compression passes back past the tip of the nipple and pushes against the soft palate. As the tongue impinges on the soft palate the levator muscles of the palate contract raising it to seal off the nasal cavity. Milk is pushed into the oropharynx and is swallowed if sufficient has collected.

f. The cycle of compression continues and ends at the posterior base of the tongue. Depression of the back portion of the tongue creates negative pressure drawing the nipple and its milk contents once more into the mouth. This is accompanied by a lowering of the jaw which allows milk to flow back into the nipple.

In ultrasound scans it appears that compression by the tongue, and negative pressure within the mouth, maintain the tongue in close conformation to the nipple and palate. Events are portrayed here rather more loosely to aid clarity.

Evidence for the former suggestion is provided in the cineradiographic films of Ardran, Kemp and Lind (1958a) (generously made available for viewing by Dr G.Ardran). One film depicts a baby at the moment of becoming detached from the breast. This is preceded by the sudden appearance of an air pocket in the oro-pharyngeal space (back of the mouth), with an equally sudden and marked retraction of the nipple in the mouth, and the general relaxation of the tissues of the mouth (tongue, soft palate). Following a momentary pause, the nipple is released by the infant.

The second suggestion is the natural inference given that milk is maintained under positive pressure in the breast, which, via the duct system, is confluent with the sinuses of the teat, and which, during sucking, projects into that part of the breast taken into the baby's mouth. The border of the mouth (lips, gums and tongue) form an effective seal against the breast, allowing negative pressure to be created. As the cycle of compression is completed the back of the tongue is lowered creating negative pressure in the pharyngeal space. The jaw is also lowered thereby releasing the base of the nipple. The nipple is drawn afresh into the oral cavity, occupying as much of the space available as there is free teat tissue to fill it. The shape of the nipple is thereby dictated by the internal geometry of the mouth (certain erroneous illustrations depict the nipple assuming it's own shape surrounded by free space [e.g. Ebrahim 1978, Goldfarb and Tibbets 1980, Helsing and Savage King 1982]). The views obtained by Smith *et al.* (1985), clearly show lateral movements of the buccal masses with shifts in pressure within the mouth. The pressure differential between the breast and the baby's mouth naturally causes expansion of the teat, and its refilling with milk from the lactiferous sinuses. At the point of maximum expansion of the teat the lower jaw is raised against the base of the nipple, thereby capturing a pool of milk within the teat.
In this respect breast feeding concurs with descriptions of bottle feeling, where, if the latex rubber from which the bottle teat is made is suitably compliant, the baby can constrict the neck of the teat and squeeze the milk out (Ardran *et al.*, 1958a). If the material is too stiff the neck cannot be constricted, so when is it compressed milk flows back into the bottle reducing the efficiency of feeding (Ardran *et al.*, 1958a). Under these circumstances, suction pressure generated by the baby will be more effective in milk removal and is likely to become the predominant mechanism (Colley & Creamer, 1958). One must remain cautious about assuming, by analogy, that negative pressure is of equal importance in removing milk from the breast.
For a long while an understanding of the mechanisms of milk transfer from mother to baby was bedevilled by the rather sterile controversy as to what acted as the propulsive force in milk removal from the breast. Intuitively, by analogy with dairy animals, 'hand milking' relies exclusively on stripping of the teat, which removes milk efficiently. This effect can be duplicated by manual palpation of the sinuses behind the human nipple to remove milk with similar efficiency. Antagonists of this viewpoint could rely on the simple demonstration that placing one's finger in a baby's mouth verified that intense suction was being exerted, while hand suction pumps were capable of removing significant amounts of milk. As with all apparently straightforward dichotomies, it is rarely the case that there is a sole determinant; rather the dual involvement of the mechanisms of both stripping and sucking are necessary for the removal of milk with maximal efficiency. Despite the semantic error in referring to the process of milk removal as 'sucking', when 'stripping' would be physiologically more correct, the term is in such common usage that there would be little to be gained from trying to change it.
The suction generated within the baby's mouth has been implicated as a major cause of nipple lesions, and so variations in negative pressure during the feed will be examined in more detail later.

The milk ejection reflex:
The one significant force in milk transfer with which I have not dealt is the mother's milk ejection or 'let-down' reflex (Waller, 1943; Asbister, 1964). This reflex causes the active expulsion of milk into the infant, with little or no involvement on the part of the infant. Waller (1943) considered this to be the predominant process in milk transfer from mother to infant. My conviction, based on the evidence from flow profiles obtained with an ultrasound flow transducer (Woolridge *et al.*, 1982), is that reflex milk ejection, as the term implies, will initially cause the active expulsion of milk from mother to infant, but for a relatively short while. This will soon subside, whereupon the reflex will maintain positive pressure within the sinuses and duct system, ensuring the continued passage of milk into the teat sinuses where it will be available for removal by stripping.
Evidence, largely by analogy from comparative animal studies, suggests that spiked release of oxytocin from the posterior pituitary causes its level in the blood to pass a threshold at which it acts upon its trigger organ - the breasts - triggering the myo-epithelial cells to contract. The myo-epithelial cells form a loose basket arrangement around each milk-storing alveolus, and are oriented longitudinally along the milk ducts. Their contraction causes the simultaneous contraction of the alveoli, driving out the stored products, and shortening of the

milk ducts, leading to their dilation. This latter effect reduces resistance to the flow of milk along the ducts (Vorherr, 1974). The milk ejection reflex is bilateral causing equal contraction of the tissue in both breasts. However, the loss of significant amounts of milk from the non-suckled breast is prevented, theoretically at least, by sphincters at the distal end of the ducts (Cross, 1977). A demonstration of the effect of the relaxation of these sphincters is seen when the baby comes off the suckled breast early in the feed, when 1-3 jets of milk may project a foot or more from the nipple. On the unsuckled breast milk simply drips out (albeit at a reasonably profuse rate).

It may be inferred that effective milk removal by the infant's stripping of the teat must take place during the period over which the myo-epithelial cells are maintained in a state of contraction under the influence of oxytocin. It is probable that once these calls relax any milk remaining in the duct system will flow back into alveoli. Here it will be effectively 'sealed off' from the infant in the absence of the positive pressure needed to maintain its transport to the sinuses of the nipple. This implies that the effective period of milk removal from the breast is limited to the time for which the myo-epithelial cells are maintained in a state of contraction by circulating oxytocin. No experimental evidence exists to show how long this might be, or how it may vary between mothers.

It should be apparent that these two opposite forces - positive pressure in the alveoli and ducts, and negative suction pressure at the nipple surface, will act synergistically, maintaining a pressure gradient in the duct system. It is this pressure differential which ensures transport of milk to the ampullae, or sinuses, of the nipple.

The newborn's natural reflexes:

Missing from the initial description, which was principally of the process of sucking, was an explanation of how the infant becomes attached on the breast. Whilst the mother has to develop the essential skills for breast feeding the human newborn comes equipped with two specific innate reflexes to help him obtain the nutrients essential for survival. In preparation for the act of suckling the first of these – the 'rooting reflex' – is elicited by the mother. This reflex has two components:

i) tactile stimulation of the skin around the mouth causes the infant to turn his head towards that source of stimulation, and

ii) his mouth gapes in preparation to accept the nipple. The former component is described often to the exclusion of the latter. Practically, for the breastfeeding mother, the latter component is more crucial as she must learn to mould this response for it to operate to her best advantage.

When the baby's mouth gapes the mother must take the initiative to bring breast and baby together, so that a second reflex - the "sucking reflex" - can be elicited. The baby gapes only briefly at first in the early days of post-natal life, but with correct reinforcement by the mother this develops into a reliable part of the overall sequence. In contrast to the neonate, the fully competent older infant (6-12 months) locates the breast visually and gapes from when the nipple is first made available to when it is satisfactorily located. The mother must learn how to effectively 'tap' her infant's natural reflexes, and develop them to work *for* her. Contrary to popular belief, attaching the baby on the breast is not an ability with which a mother is innately endowed; rather it is a learned skill which she must acquire by observation and experience. In the absence of the 'extended family' it is the midwife who must pass on these essential skills.

The 'sucking reflex' is elicited by stimulation (tactile/chemical) of the *palate* by the nipple. It may seem improbable that while the tongue is so well endowed with taste receptors it should be the relatively insensitive palate which is the link in the chain leading to functional feeding. However, this may be viewed as being highly adaptive. As the *tongue* and *lower jaw* provide the necessary motive force in milk expulsion by the baby, the breast tissue overlying the milk ducts should be apposed to these structures. This can be ensured by the part of the mouth *opposing* them being the target for stimulation by the nipple. Both traditionally, and in more recent texts (Marmet & Shell, 1984), it has been stressed that the mother should get 'as much of the areola in as possible'. This advice misses the point that the amount of areola visible to the mother above the baby's mouth is not directly relevant to the efficiency of feeding (perversely, the less that is showing above, the more may be exposed below, if, as is often the case, the nipple is taken in asymmetrically). So for his part the baby would appear adapted to the task of grasping an adequate teat by possession of the sucking reflex, which is stimulated by contact between the nipple and palate. The mother, on her part, must strive to ensure that when breast tissue is grasped by the baby, along with the nipple, most lies adjacent to the tongue and lower jaw. In order to achieve this when attaching her baby the mother must first 'plant' the lower rim of the baby's mouth well below the nipple, and then almost 'fold' the breast into the baby's gaping mouth. Once again, the mother should learn how this natural reflex operates, and develop her skills to make it work for her.

Failure to adequately stimulate the palate early on, through unsatisfactory attempts at fixing, may be a common source of breast-feeding problems. In particular, it can lead to subsequent refusal and rejection of the breast in favour of objects capable of providing the stimulation necessary to elicit sucking (e.g. artificial teats on bottles). Delaying the process for too long after birth may lead, through ineffective milk removal, to engorgement, which will further compound the problem and may prolong it unacceptably.

Variation in negative pressure with sucking rate:
Negative pressure is not applied uniformly with the same intensity at every suck, but rather varies with the baby's sucking pattern. Studies of babies feeding on an artificial teat (Brown, 1973; Wolff, 1968) have shown that the human newborn has two distinct patterns of sucking- 'nutritive' and 'non-nutritive' sucking - operationally defined by the presence or absence of fluid, respectively. On the breast these patterns are not so distinct (Drewett & Woolridge, 1979; Bowen-Jones, Thompson & Drewett, 1982), although as early as 1948, they were discriminated into 'basic (N1)' and 'secondary (N2)' frequencies (Balint, 1948). I will use more recent terms as they are more descriptive, but without meaning to imply a factual knowledge of milk flow other than by inference. I rase the issue of these two types of pattern because the level of negative pressure generated differs between the two.

Non-Nutritive sucking occurs in short, fast bursts at a rate of up to two sucks per second. This would appear homologous to Balint's 'Secondary frequency', and sucking on the breast most closely resembling this pattern is seen when the baby first goes onto the breast, and little or no milk is available prior to reflex milk ejection. Gunther (pers comm) uses the expression 'call-up' sucking to refer to this pattern, which implies a functional role in the elicitation of the reflex release of milk (this is plausible, but is, as yet, unsubstantiated). *Nutritive* sucking, in contrast, occurs at a slower pace (one per second), and early in the feed, once milk has started to flow, sucks appear in a continuous stream. As the feed progresses, sucking becomes fragmented into bursts now separated by pauses of longer duration than are typically seen during 'non-nutritive' sucking. At the start of each burst there may be 2-3 fast sucks typical of the previous class of sucking (termed 'restart frequency' by Balint [1948]). In addition to reflecting low milk flow, these sucks may serve to draw the nipple out, filling the oral cavity and reversing any loss of grasp during the pause; once again forming an adequate teat for the expression of milk.

At the slow rate of sucking each cycle lasts approximately 1 second, and the effective period over which negative pressure is applied is roughly half of this (0.5s). During this time the baby exerts maximum intra-oral suction, *but* as milk issues from the nipple it fills the oral cavity relieving the negative pressure, and resulting in the need to re-apply suction in a repetitive manner. Thus, the expansion of the teat in the oral cavity, and its filling with milk from the nipple, both act to reduce the peak negative pressure exerted on the nipple. It should be apparent that either an inadequate 'mouthful' of breast tissue by the baby or impaired milk flow will mean that the nipple is likely to be subjected to unrelieved negative pressure.

At the faster rate the total cycle time is only half a second, with a reduction in the effective suction phase to 0.25s. As a result, suction does not reach peak pressure when milk flow is absent. This phenomenon can be seen in published records of suction pressure (Halverson, 1938; Mytten, 1951). One possible inference is that physiological variability in sucking pattern may act as a natural protective mechanism preventing exposure of the nipples to maximum pressure in the absence of milk flow. The significance of these suppositions will become apparent during discussion of the possible causes of nipple lesions.

Gunther (1945) investigated the level of basal resting pressure during the rests between bursts of sucking for its possible involvement in causing nipple lesions, and little can be added to her analysis. It is plausible, however, that the exertion of high resting pressures by the infant may be an adaptation to prevent the nipple retracting from the mouth whilst resting. Highly retractile breast tissue or an inadequate teat may *cause* individual infants to adopt this strategy to prevent loss of the teat from the mouth.

Conclusion

A sound understanding of the mechanisms of milk removal from the breast is essential if one is to advise mothers correctly on feed management. As arbitrary rules about management, set up some decades ago, are found to be of little value (if not positively harmful) and are discarded, greater emphasis must be placed on the development of the essential practical skills necessary to ensure the correct attachment of the baby on the breast, in order to allow natural, unhampered breast-feeding to be undertaken.

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*In each of these texts the relevant diagrams appear to be derived from Applebaum (1970), which are themselves apparently copied from Breast Feeding by F C Naish, (1956) 2nd Edn, Lloyd-Luke Ltd, London, p28.