Unravelling our beginnings

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The history of man for the nine months preceding his birth would, probably, be far more interesting and contain events of greater moment than for all the three score and ten years that follow it.
(Samuel Taylor Coleridge)

Peter Hepper *on the embryonic science of fetal psychology.*

FOR 38 weeks of our lives, we live underwater, in relative darkness, warm, maybe even cosy. We develop faster than at any other time. We experience noise and smells… frequently experienced stimuli become familiar, perhaps reassuring. We exercise regularly. Matters of great importance for our future lives are taking place, yet we have no memory of this time. Further, as if to deny any relevance of this period, it is only when it ends that our official age begins.

However, these 38 weeks before birth were not irrelevant and the study of fetal psychology is unravelling the significance of the prenatal period and behaviour for our development. In this article, I examine the behaviour of the fetus, its importance for development, and how a greater understanding of fetal behaviour may be used to improve the health of the fetus.

AGE OF FIRST FETAL BEHAVIOURS

Behaviour	*Gestational age (weeks)*
Just discernible movement	7
Startle	8
Hiccup	9
Fetal breathing movements	10
Hand–face contact	10
Yawn	11
Sucking and swallowing	12
Rooting	14
Eye movements	16

The behaviour of the fetus

Ultrasound technology has provided a window through which the behaviour of the fetus may be observed. Although pregnant women report feeling their baby move at around 16–20 weeks of gestation, ultrasound observations have revealed that the fetus begins to move at 7–8 weeks (de Vries *et al.*, 1985). These first movements appear slow and originate in the spinal cord: the back may flex or extend, and this results in passive movements of the arms and legs. The types of movement exhibited by the fetus expand rapidly and by 14–15 weeks virtually all the movements the fetus will exhibit have emerged (see box).

As the fetus develops, its movements become organised into periods of activity and inactivity. This culminates at the end of pregnancy with the emergence of four behavioural states – quiet sleep, active sleep, quiet awake, active awake – precursors of the behavioural states seen in newborns (Nijhuis *et al.*, 1982).

The examination of fetal movements has produced some fascinating discoveries. For example, handedness is observed from 10 weeks of gestation (Hepper *et al.*, 1998). Intriguingly, there have been no reports of hemispheric differences at this age, which may suggest that it is differential left- and right-sided movements that lead to lateralisation of brain function rather than the other way round. Rapid eye movements, associated with dreaming in adults, have been observed in the last third of pregnancy (Horimoto *et al.*, 1993).

Early views of the fetus portrayed its environment as one of sensory deprivation. Research has revised this view (Hepper, 1992) and demonstrated that the fetus has considerable sensory abilities. The only sense unlikely to be stimulated naturally in the womb is that of vision, as the mother's clothes and tissue will block out light.

The first sense to develop is that of touch (Hooker, 1952). By eight weeks of gestation the fetus responds to touch around the lips and cheeks. By 14 weeks most of its body, excluding the back and top of the head, responds to touch. The fetus touches its face from 10–11 weeks and contact with the umbilical cord and uterine wall, and possibly other womb mates, provides tactile stimulation.

Flavours from the mother's diet pass into the amniotic fluid, so when the fetus begins to swallow this fluid, around the 12th week of gestation, it may experience the flavours of its mother's diet (Mennella *et al.*, 1995). By 15–16 weeks the fetus responds to the flavour of the amniotic fluid (Liley, 1972) – swallowing more if the fluid tastes sweet but less if it tastes 'bitter'.

The fetus responds to sound from 22–24 weeks (Hepper & Shahidullah, 1994). Initially, responses are found only in the low-frequency range (250–500Hz) of adult hearing (20–20000Hz), but this range expands as the fetus matures. In late pregnancy, the fetus can discriminate between different voices (Lecanuet *et al.*, 1993) and speech sounds – 'BIBA' and 'BABI' (Shahidullah & Hepper, 1994). The uterine environment of the fetus is quite noisy (Querleu *et al.*, 1988). The mother's heartbeat, blood flow and digestive system all contribute to the fetus's auditory world. Sounds from the external world can be heard, although with some attenuation by the mother's tissues. Interestingly, there is little attenuation around 125–250Hz, the fundamental frequency of the human voice. Thus, the mother talking and other speech sounds in the environment will be readily heard and will form a major part of the fetus's environment (Querleu *et al.*, 1988).

One sensory ability that has aroused considerable interest is that of pain sensation (Glover & Fisk, 1999). The determination of whether the fetus feels pain is made more difficult by the fact that pain is a subjective phenomenon. Pain responses have been observed in the premature infant from around 24–26 weeks, a time when the neural pathways for pain are first formed (Fitzgerald, 1993). Biochemical stress responses to needle punctures during blood transfusions are found from 23 weeks (Giannakoulopoulos *et al.*, 1994). These, however, are all indirect measures of pain, and debate is rife as to whether the fetus feels pain. Although lacking a definitive answer, this does not prevent consideration of the use of analgesia for the fetus and it may be appropriate to err on the side of caution and administer analgesia irrespective of whether the fetus feels pain or not (Glover & Fisk, 1996). However, the analgesia itself may have adverse consequences; more research is needed to resolve this issue.

Whether the fetus can learn has attracted considerable interest, possibly because learning is often seen as the pinnacle of adult achievement. Early studies of learning in the 1930s and 1940s, perhaps reflecting the zeitgeist, demonstrated classical conditioning in late pregnancy (Ray, 1932). Peiper (1925) reported a decrement in fetal response to a repeated sound (car horn), and more recently the fetus has been demonstrated to habituate to auditory stimuli from around 22–24 weeks (Hepper & Leader, 1996).

Newborns prefer their mother's voice to that of an unfamiliar female (DeCasper & Fifer, 1980), a preference that is acquired prenatally. Newborns prefer music they have heard prenatally to that which they have never heard (Hepper, 1991). Interestingly, this preference can be observed at 36 weeks but not 30 weeks, which may indicate that learning of familiar sounds or tunes occurs after 30 weeks.

The fetus also learns about tastes and smells. For example, if the mother eats garlic during her pregnancy her newborn exhibits less of an aversion to garlic than newborns whose mothers did not eat garlic (Schaal *et al.*, 2000). Newborns show a preference for the odour of their mother over that of another female (Macfarlane, 1975) and orient to their own amniotic fluid, both observations suggestive of prenatal learning of odours and tastes.

'The fetus is continually active in and reactive to its environment'

Whether long-term preferences can result from prenatal learning is unknown. Newborn preferences for music acquired prenatally disappear by three weeks of age in the absence of any postnatal exposure (Hepper, 1991). However, the ability of the fetus to learn has led some to believe that development can be enhanced through programmes of prenatal stimulation. As yet there is no good scientific evidence to demonstrate this.

The importance of fetal behaviour

The fetus is continually active in and reactive to its environment. But *why* does the fetus move, sense its environment, learn? It is possible that the behaviour and experiences of the fetus have no impact on its development and are mere byproducts of the maturation process. However, research suggests the behaviour of the fetus is important for its development both before and after birth (Hepper, 1996), ensuring its survival and beginning its integration into the social world.

Adapting to the womb The fetal environment is very different from that experienced after birth. In order to survive in this environment the fetus may exhibit behaviours suited to this environment – ontogenetic adaptations (Oppenheim, 1984). To date, there has been little research examining this aspect of the fetus's behaviour. It may be that some of the reflexes exhibited by the newborn are required by the fetus to aid its movement during birth.

Practice makes perfect One key role for prenatal activity is to practise behaviours that are essential for survival after birth; for example, fetal breathing movements. These begin at 9–10 weeks and occur around 30 per cent of the time at 30 weeks (Patrick *et al.*, 1980). Although there is no air in the womb these breathing movements help the neural pathways responsible for breathing to mature, ensuring a fully operational system when required at the moment of birth.

Forming joints and muscles The movements of the fetus are essential for the formation of the joints and muscle tone (Drachman & Sokoloff, 1966). Initially, the joints develop with rough surfaces; but as the fetus moves, the joints are reshaped and develop their smooth surfaces to enable complete mobility. Absence of movement in joints has been linked to malformation, (e.g. club foot).

Getting ready for the breast Prenatal olfactory learning may facilitate the establishment of breast-feeding. Although alternatives exist to breast-feeding today, in the evolution of the mother/fetus/newborn biological system alternatives to breast-feeding were not available. If the individual was to survive its only source of nourishment in the immediate postnatal period was breast milk. The same processes that flavour the mother's breast milk also flavour the amniotic fluid, so the fetus may learn about the flavour of breast milk from swallowing amniotic fluid.

Mothers whose diet changes across the birth period have much more difficulty in establishing breast-feeding than mothers whose diet remains the same.

Attachment The ability of the fetus to recognise its mother's voice and smell may be important for the processes of attachment and exploration. Whilst the newborn has a rudimentary sensory system able to process auditory and chemosensory information, and to a lesser extent visual information, it knows nothing about its environment. Imagine yourself with sensory systems able to process information but in which nothing is familiar – disorientation indeed. It would make good sense for the newborn to be able to recognise one familiar object in this sensory milieu, and even better sense if this object is its mother and primary caregiver. Recognition by sound and smell are also advantageous as they operate remotely; that is, the mother may be out of visual contact with her baby but the baby can hear and smell her over some distance, providing a familiar recognisable cue in the newborn's environment.

Language Experience with speech sounds in the womb may begin the process of language acquisition (Moon & Fifer, 2000). Newborns recognise and prefer their mother's language, and are able to discriminate this from an unfamiliar language (Moon *et al.*, 1993). Recordings from the womb reveal that speech sounds clearly emerge from the background noise (Querleu *et al.*, 1988). This exposure may be the beginning of language acquisition.

Boosting brain cells At a more general level, experience during the prenatal period may be important, or even essential, for normal development, especially of the brain. It is well established that the nervous system develops in response to the experiences it receives and from activity generated within the system (Lagercrantz & Ringstedt, 2001). The prenatal period marks the most rapid period of development of our brain. At its peak some 250,000 brain cells are being produced every minute. The normal prenatal environment (of changing sensory information, fetal activity and reactivity) may provide necessary and essential stimulation for the formation of the CNS and subsequently its function.

DISCUSS AND DEBATE

The fetus exhibits REM – does it dream? If so, what about?

Has psychology ignored the prenatal period to its detriment in understanding behaviour?

Is there a role for developmental psychology and psychobiology in debates about reproductive issues?

Reducing smoking and drinking less alcohol in pregnancy is beneficial for the fetus; but if this increases maternal anxiety, could the fetus be worse off?

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The abortion debate

With evidence accumulating of the fetus's behaviour and its importance for development, these findings have been used in social, moral and political debates surrounding reproductive issues – especially abortion. However, their bearing on this discussion has been questioned. The debate over abortion often revolves around the beginning of life, variously argued to occur at conception, through the point of 'sustainable' life outside the womb (around 22–26 weeks), to the moment of birth. The fetus's behaviour may not be conclusive to this determination.

Many factors contribute to an individual's views on abortion and the behaviour of the fetus may be one factor in this. It is not my intention to enter into the debate here, but rather to raise two issues of relevance to the use of behaviour in this debate. First, the onset of abilities during the prenatal period is not an all-or-none process, but rather a gradual process of development, expansion and refinement following initial appearance. Thus, attempts to determine the start point for a particular behaviour face similar and familiar problems to those when attempting to determine the start of life. Second, care needs to be taken in the interpretation of human fetal behaviour. Although the human fetus can learn, identical learning abilities have been found in other mammalian fetuses, bird embryos, reptile embryos, amphibian embryos and even insect pupae (see Sneddon *et al.*, 1998, and references therein). Whilst research on the behaviour of the fetus may contribute to the abortion debate and help inform individual views, it does not hold the magic key to resolve the debate.

Improving fetal well-being

As more knowledge is gained about the behaviour of the fetus and the factors that influence development, opportunities are presented to use this to enhance the health of the fetus.

Despite a number of techniques to assess fetal well-being (e.g. analysis of genetic/chromosomal constitution, structure, and autonomic function), none directly assess the functioning of the brain. Since the behaviour of the fetus directly represents the functioning of its nervous system, observation of the fetus's behaviour provides an excellent means of assessing neural function and dysfunction (Hepper, 1995).

Aberrant patterns of behaviour have been observed in fetuses with chromosomal abnormalities, neural tube defects, maternal illness (e.g. diabetes) and those exposed to illegal and social drugs (e.g. Hepper *et al.*, 2005; Nijhuis, 1992). Moreover, analysis of behaviour enables the severity of effect to be determined (Hepper, 1995). Examining the behaviour of the fetus has advantages when assessing the effects of drugs or potential teratogens. As behaviour reflects the output of the brain, it can provide an assessment of function independent of information on input, which may be difficult to obtain (e.g. how much alcohol was consumed). Assessing behaviour examines the actual effect exposure to alcohol, or other substances, has had on brain function. Although only at the very early stages of development, analysis of the fetus's behaviour may provide important information on fetal health, leading to improved diagnosis and better treatments.

The action of drugs (e.g. thalidomide) on the fetus demonstrates that prenatal influences exert a long-term effect. Recently the role of experiences in influencing the development and function of physiological systems has been recognised, suggesting certain adult diseases have fetal origins – the fetal origins of adult disease hypothesis (Barker, 1992). Evidence is now accumulating that maternal psychological factors may influence the fetal environment exerting a long-term influence on the developing fetus. This research poses significant challenges for our treatment of the prenatal period.

Recent evidence has suggested an important link between maternal anxiety during pregnancy and outcome after birth (O'Connor *et al*., 2003). High prenatal maternal anxiety levels have been linked with lower mental and motor development at eight months of age, lower mental development at two years and higher levels of behavioural and emotional problems at six years nine months. It is argued that maternal anxiety influences the functioning of the maternal hypothalamic-pituitary-adrenal axis, which in turn influences fetal brain development, resulting in the subsequent poorer psychological and behavioural performance. This poses major challenges for the public health agenda. Considerable resources have been employed in attempts to reduce the consumption of alcohol and smoking by pregnant women. What could or should be done to reduce maternal anxiety if this effect on brain development and performance is further confirmed? There is no easy answer, and it is obvious that the scale of any such intervention would be huge and complicated. But this should not mean that the opportunity to enhance development should be ignored.

The first 38 weeks of our development has been shrouded in mystery, but now the embryonic science of fetal psychology is revealing the importance of this period for the rest of our lives. As well as advancing our knowledge of the ontogenetic processes before birth, the greater understanding of prenatal development presents an opportunity to promote the health and well-being of the fetus and provide individuals with the best start in life possible.

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WEBLINKS

Early development videos: *health.discovery.com/convergence/ultpregnancy/video.html*

Obstetric ultrasound: *www.ob-ultrasound.net*

The Visible Embryo: *www.visembryo.com/baby/index.html*

Fetal Behaviour Research Centre: *www.psych.qub.ac.uk/research/fbrc*

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