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See also: AIDS and HIV; Birth Complications and Outcomes; Breastfeeding; Endocrine System; Prenatal Development; Screening, Prenatal; Teratology.

Suggested Readings


Relevant Websites


Introduction

A single, fertilized cell develops into the complex organism that is a human newborn infant in just 266 days. The explosive rate of growth and development during this period is unparalleled at any other point in the lifespan. A resurgence of interest in the prenatal period as a staging period for well-being and disease in later life has been fostered by the enormous attention devoted to the hypothesis of ‘fetal programming’ advanced by D. J. Barker and colleagues. This rapidly emerging field of study focuses on the role of maternal and fetal factors in adult organ function, including the brain and nervous system. That earlier circumstances, including those during the prenatal period, might affect later development is hardly newsworthy to developmentalists. In 1929, the foundation of the Fels Research Institute in Yellow Springs, Ohio, was based on a longitudinal study of child growth and development that commenced with intensive investigation of the fetal period. Although investigators had limited access to the fetus due to the primitive research tools available to them, their research questions and orientation were truly prescient and the results they generated were surprisingly consistent with more recent findings using more sophisticated technologies.

Human gestation encompasses the period of time from conception to birth. By convention an additional 2 weeks is added to account for the average period of time between the last menstrual period and ovulation so that the average term gestation is 40 weeks long or 280 days. However, normal full-term birth spans the gestational period from 37 to 41 weeks. Pregnancies that end before 37 weeks are referred to as pre-term; those at and beyond 42 weeks are post-term. Survival of preterm infants has improved dramatically during the last several decades as a result of improvements in neonatal intensive care. However, the age of viability, or the earliest gestational age at which some babies can survive with aggressive technological support, is currently 23 weeks’ gestation. Prior to this time, development of the respiratory and other organ systems is insufficient to sustaining extrauterine life. At the other end of the spectrum, pregnancies that last too long are also hazardous. However, current obstetric practices have drastically reduced post-term gestations through the use of induced or surgical deliveries.

The fertilized ovum enters the uterine cavity shortly after conception. Mitotic division generates the blastocyst, a hollow ball of cells that becomes implanted in the wall of the uterus within the first 2 weeks. Weeks 2–8 comprise the embryonic period, during which time differentiation of organs and structures proceeds rapidly. By the ninth week after conception, approximately 95% of all structures within the body are developed although the embryo weighs less than 10 g and is only 50 mm long. This week also marks the transition from the embryonic to fetal period, although there is no clear physical demarcation. The embryo and fetus develop in the intrauterine cavity within an amniotic sac, which is filled with amniotic fluid. During the embryonic period, the structures necessary to support development originate and progress through a series of stages, ultimately resulting in the umbilical cord and placenta. The placenta provides nutrients, exchanges gases, and manufactures hormones vital to maintenance of the pregnancy. A mature placenta is intended to function for a full-term pregnancy; thus, post-term risks to the fetus are often due to the deterioration of the placenta’s ability to optimally support the fetus. The circumstances that stimulate labor and delivery are not well understood, although there is significant evidence that signals from the fetus itself serve as impetus.

The fetal period proceeds until birth and is marked by final development of organ morphology and function, including prolonged development of the brain and nervous system. The ‘hardware’ of the brain – neural tube closing, neuronal and glial cell proliferation and migration – commences early in gestation, while the ‘software’ elements of synaptogenesis, process elimination, and myelination continue through term and after birth. Organs are most vulnerable to insult when they are developing most intensively. Thus, exposure to potentially harmful substances during pregnancy has consequences for structural malformations of most organ systems only during the embryonic period or shortly thereafter. However, the potential for harmful effects of functional brain development, with implications for cognitive and behavioral development after birth, persist throughout pregnancy. Figure 1 provides a schematic description of the shifting vulnerabilities during gestation.

The terms growth and development are often used interchangeably but they refer to distinct processes. Growth is typically defined as an increase in cell size or number; development implies differentiation of function or complexity. The remainder of this article focuses on fetal neurobehavioral development, a set of features of prenatal functional development that are measurable and observable functional indicators that are presumed to reflect development of the nervous system. The study of fetal neurobehavioral development reflects a backward or downward extension of principles and theories that have been applied since the early 1970s to characterize infant behavior. In fact, developmentalists who study the fetus commonly assert that “nothing neurologically interesting happens at birth.” While it is obvious that birth presents transitional challenges for a number of organ systems, such as the circulatory and respiratory systems, it is not well recognized that by the end of gestation the fetus demonstrates virtually the same behavioral repertoire as a newborn infant. Put another way, all behaviors exhibited by neonates have been observed at some point during the fetal period.
Development during the prenatal period proceeds along a continuum, with behaviors becoming incrementally more complex and varied as gestation proceeds. Like all other developmental periods, the fetal period is not monolithic; behavior in the early fetal period is largely reflexive and involves the entire body while behavior near term is far more fluid, integrated, and distinct. Although no other developmental period yields the same potential to reveal the complexity of human ontogeny, no other period of developmental inquiry is so heavily dependent on technology to answer even the most basic of questions. Before proceeding to detailing current understanding about prenatal developmental ontogeny, a brief review regarding technologies necessary to view and monitor the fetus is provided.

Fetal Monitoring Techniques

Although speculation about the nature of fetal behavior has existed since antiquity, the advent of real-time ultrasound in the early 1970s enabled modern scientific investigation of prenatal development. Visualization can reveal specific behaviors (e.g., thumb-sucking), qualitative aspects of movement (e.g., fluidity of flexion and extension), structural features of the fetus (e.g., size), and characteristics of the uterine milieu (e.g., volume of amniotic fluid). In addition, refinement of techniques to monitor fetal heart rate and its patterning, using Doppler ultrasound, has provided another important source of information regarding prenatal neural development. Doppler has also generated techniques to detect fetal motor activity without ultrasound visualization and makes it possible to measure the amount of blood flow and resistance in maternal and fetal vessels, including umbilical, cerebral, and uterine arteries. The most recent technological advance is the development of three-dimensional (3D) and so-called four-dimensional ultrasound (i.e., 3D image plus addition of a fourth dimension of real time motion) that allows visualization of details, such as fetal facial expressions and hand movements, which were not previously possible. Figure 2 presents examples of traditional two-dimensional (2D) and 3D images.

Although 3D technology holds great potential for future studies, it is yet to be implemented broadly. Almost all knowledge about human prenatal development has been generated by information from a mixture of existing ultrasound methods, including 2D ultrasound and fetal heart rate monitoring. Regardless of how sophisticated ultrasound may become in the future, the human fetus will always remain slightly beyond our actual reach.

Fetal Neurobehavioral Development

Theoretical orientations regarding neurobehavioral development early in the postnatal period generally focus on...
four domains of functioning: autonomic, motor, state, and responsive/interactive capacities. These domains are hierarchical in nature such that sufficient maturation of function of each precedes emergence of the next. That is, in order to sustain interaction with the environment, one needs to be able to maintain a certain degree of state control; in order to maintain state control, one needs to inhibit unnecessary motor activity, and so on. Information about prenatal development can also be organized in this manner as their ontogenic origins are rooted firmly in the fetal period. In the fetus, the specific aspects of functioning within each domain include (1) fetal heart rate and its patterning, (2) quantitative and qualitative aspects of motor activity, (3) the emergence and consolidation of behavioral states, and (4) interaction with the intrauterine and external environments.

**Fetal Heart Rate**

In infants and children, patterns inherent in continuously monitored heart rate are frequently used indicators of the autonomic nervous system. In particular, features of variability in heart rate are considered to reflect the development of parasympathetic processes related to the vagus nerve (i.e., vagal tone) and have been linked to aspects of infant and child behavior and development. More information exists about the development of fetal heart rate than any other domain. Noninvasive methods to measure fetal heart rate by placing a simple Doppler transducer on the maternal abdomen have been commonly used in clinical obstetric practice and research for decades and a great deal is known about development of components of the fetal heart rate. A fetal heart beat is detectable near the sixth gestational week. As the cardiac system rapidly develops, heart rate increases over the next 4 weeks to a baseline rate of approximately 160 beats per min (bpm). Heart rate declines to approximately 135–140 bpm by term, although normal limits span a wide range.

Patterns in fetal heart rate during the prenatal period and labor are more revealing about nervous system development than is heart rate. In fact, the principal means available to determine general fetal well-being or distress relies on the direction and magnitude of periodic fluctuations in heart rate. Fetal heart rate that is characterized by variability over time and includes transient, acceleratory excursions of heart rate well above baseline is interpreted as a reassuring sign of fetal health. In contrast, lack of variability and deceleratory episodes (i.e., significant slowing of heart rate well below baseline levels) can be indicative of neural compromise or distress. The heart rate decline observed during gestation is accompanied by an increase in the number and size of accelerations, a reduction in deceleratory periods, and an increase in beat to beat and longer-term components of heart rate variability. Both have been attributed to changing cardiovascular needs and cardiac functioning in the developing fetus that have both non-neural and neural influences. Maturational changes in the innervation of sympathetic and parasympathetic autonomic processes and progressive assumption of higher levels of central mediation are among the neural components of these gestational changes.

**Fetal Motor Activity**

During gestation, fetal movement progresses from uncoordinated movements that involve the entire body to more integrated, narrow, behavior patterns. Spontaneously generated motor activity is present during the embryonic and early fetal periods. Figure 3 shows the gestational age at emergence of 15 types of motor behaviors studied in a sample of 11 fetuses observed on ultrasound at weekly intervals early in gestation.

There is progression in the emergence of each behavior, from the least to the most differentiated. In addition, there is greater individual discrepancy in the emergence of more complex patterns, suggesting that these may be
more reflective of the development of higher-order brain processes. Note that this figure shows only the first observed incidence for each; once a behavior is expressed, it continues to persist throughout gestation.

Specific movements are believed to serve preparatory or functional roles that increase survivability at birth. For example, fetal breathing motions begin early in gestation and become more common over time, so that by term the fetus exhibits fetal breathing movements approximately a third of the time. Although air is not a component of the intrauterine environment and these movements serve no role in oxygen regulation, they probably reflect rehearsal of behavior patterns of the diaphragm and other muscles that are central to respiration. Fetal hiccupping and yawning are commonplace although neither has clear functional significance. However, fetal sucking movements in general and thumb-sucking in particular are also common activities that may strengthen neural connections necessary for the successful transition to postnatal feeding. It also suggests that non-nutritive sucking (i.e., sucking that is not associated with nutrition) may serve a self-soothing or regulatory role both before and after birth. Other behaviors play clear roles in optimizing the intrauterine environment. For example, fetal swallowing assists in regulation of the amount of amniotic fluid present. Development begins with the fetus in a breech, or head up position; fetal motor behaviors consistent with stepping along the intrauterine wall have been observed as the fetus makes the transition from a breech to vertex position (i.e., head down) position midway through gestation. This has raised speculation that some fetuses that remain breech by the time of delivery differ in their motor development from those who successfully assume the vertex presentation.

Animal models have provided developmental psychologists with an important source of information to study the adaptive significance of specific behaviors prior to birth because they may be studied either with special preparation of eggs, for precocial avian species, or with preparations that make viewing the developing fetus more accessible in mammalian species. For example, newborn rat pups display a specific type of locomotion that is necessary to early survival but disappears soon after birth; this coordinated behavior originates during the prenatal period. Experimental manipulations in animal models have also served to identify basic mechanisms and progressions of behavioral expression in the developing embryo of fetus as well as the contributions of both intersensory experience and the intrauterine environment in shaping ontogeny.

Fetal movements are normally not felt by pregnant women until the 16th to 18th week of pregnancy. After this time, women perceive most large amplitude, prolonged movements but are poor detectors of other spontaneous or evoked fetal movements, detecting as few as 16% of movements at term. This makes reliance on maternal report an unsuitable source of data in studies of fetal motor activity; instead investigators rely on ultrasound-visualized or

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**Figure 3** Gestational age of emergence of specific fetal motor behaviors in a sample of 11 fetuses viewed serially with ultrasound. Adapted from de Vries J, Visser G.H, and Prechtl HF (1982) The emergence of fetal behaviour. I. Qualitative aspects. *Early Human Development* 7: 301–322.
Doppler-detected measurement of fetal motor behavior. Most longitudinal studies report that the fetus becomes less active as gestation advances although movement amplitude or intensity increases as the fetus becomes larger. Inhibition of behavior is considered a hallmark of early child development in the postnatal period; thus, this pattern appears prenatally. In the latter half of gestation, fetuses move approximately once per minute, and are active between 10% and 30% of the time. Such estimates vary, in part, because of differences in how the end of one movement and beginning of the next are defined. Fetal activity patterns exhibit rhythmic periodicities during relatively short cycles during the day as well as circadian rhythms, with fetal motility peaking late in the evening. Although sex differences in motor activity are commonly observed in studies of infants and young children, sex differences in fetal motor activity are not apparent.

**Fetal Behavioral State**

During the second half of gestation, fetal heart rate and movement patterns become integrated such that fetal heart rate increases and becomes more variable when the fetus is moving and is lower and less variable when the fetus is still. This coupling develops in a predictable fashion and has been most often attributed to centrally mediated co-activation of cardiac and somatomotor processes; thus, it provides information regarding the integration of neural processes. Near 32 weeks’ gestation, coupling of these two aspects of development is joined by synchronous activity of other kinds, particularly fetal eye and breathing movements. In the late 1970s, investigators determined that periods in which there were predictable co-occurrence of specific patterns in three parameters – heart rate, motor activity, and eye movements – represented behavioral states that correspond to the sleep–wake states observed in the newborn. Four fetal behavioral states were discerned, labeled 1F, 2F, 3F, and 4F, in concert with state scoring methods developed for neonates. These fetal states approximate quiet sleep (1F), rapid eye movement (REM) sleep (2F), quiet waking (3F), and active waking (4F). Investigations conducted since that time tend to confirm the relative comparability of these states to those of newborn infants. In the postnatal period, behavioral state provides the context for evaluating and interpreting all other behaviors. As the fetus matures, state parameters gradually develop linkage between two parameters and ultimate coincidence accompanied by predictable state transitions during which near-simultaneous changes occur in all parameters. Mature states do not emerge until near 36 weeks; prior to that time, fetuses are most often observed in either indeterminate states or those that are best characterized simply as general periods of quiescence or activity, and the transitions between them are indistinct. Figure 4 presents characteristic recordings of 8 min each of a fetus in quiescence and activity. Understanding of the central mechanisms underlying maturation of state in the fetus are not yet well elucidated although patterning in temporal activation linked to the reticular formation has been implicated.

Once states coalesce, fetuses spend most of the time in either quiet or active sleep. Periods that seem consistent with wakefulness are less common, and in particular, episodes in which the fetus seems to both quiet and awake are rarely observed, leading some to speculate that such a period either does not exist, or that perhaps investigators do not know how to recognize it. The newborn infant also expresses a fifth behavioral state encompassing fussiness and crying, but such activity is not included in the traditional definitions of fetal states. However, if developmentalists are to stand behind their observation that the newborn behaves in the same way as a near term fetus does, prenatal crying should exist. Because the larynx must be surrounded by air to produce an audible cry, but this is not the case in the fetus, other indicators of crying would need to be detectable. Anecdotal evidence of fetal crying has existed for a number of years, and recently ultrasound has identified inspiratory and expiratory diaphragmatic patterns that appear to be a fetal analog to an infant crying in response to a loud sound. It is important to note, however, that if this fifth state is confirmed, it, like other states, appears only near the end of gestation.

**Fetal Responsivity**

Human fetal sensory systems develop in an analogous order to those of nonprimate species: cutaneous, vestibular, auditory, and lastly, visual. It is fairly well accepted that the fetus has the capacity to feel pain and other sensations, but again, this would be expected from a neurological basis only near the end of term. The fetus exhibits behaviors that seem to generate information about the intrauterine environment – grasping the umbilical cord, licking the placenta, pushing off the uterine wall with hands and feet. Interest in demonstrating fetal responsivity to stimuli originating outside the uterus dates to the 1930s Fels Study; preferred stimuli at that time included door buzzers and warning horns. Women often report feeling fetal motor activity in response to loud sounds. More recently, fetal responses ranging from heart rate surges, abrupt changes to an active behavioral state, and startles to more subtle responses, including bladder emptying and reduction in fetal breathing movements, have been generated using a variety of vibroacoustic devices. Vibroacoustic stimulation refers to auditory and/or vibratory stimuli activated on or near the maternal abdomen, usually above the fetal head. Because fetal hearing matures relatively early, and sound is efficiently conducted in a dense medium (e.g., amniotic fluid), the use of loud or intense stimuli has generated a number of
concerns about safety and the potential for causing fetal discomfort. Nonetheless, it is clear that from at least midway through gestation, the fetus can respond to stimuli that originate outside of the uterus.

The question of whether the fetus responds to more nuanced stimuli in a manner indicative of higher cognitive or information processing is extraordinarily difficult to answer conclusively. Consider for a moment the challenges of assessing memory in infants. Babies cannot directly communicate what they know; they fall asleep unpredictably, have little motor control, and in general behave in ways that limit our ability to test them. Add to these challenges the additional feature of not being able to actually see the subject of testing and you begin to approach the difficulties of this type of fetal research. Nonetheless, the fetus seems capable of habituation, a primitive form of sensory learning requiring response decrement to repeated presentations of invariant stimuli. Habituation, as measured by successive reductions in motor and heart rate responses to vibroacoustic stimuli, has been observed late in pregnancy. Such observations suggest that the mature fetus has rudimentary learning

**Figure 4** Doppler-generated segments over a period of 8 min of fetal heart rate (upper, horizontal line) and fetal motor activity (lower, vertical lines) in a fetus at 36 weeks’ gestational age (a) reflecting periods of quiescence (1F) and (b) active waking (4F).
capacities. However, because fetal research is technically difficult to implement and often not conducted with the same experimental rigor as studies with infants, dishabitation is often not assessed. This makes it difficult to determine whether studies have shown true habituation in the fetus rather than simple response fatigue.

Given the difficulties in measuring subtle fetal responses, most studies on fetal learning capabilities expose fetuses to stimuli during gestation but test on recognition after birth. Virtually all of these focus on fetal ability to learn features of auditory stimuli. Although the intrauterine environment conducts external vibroacoustic stimuli well, this is not the only source of auditory stimulation. The background noise level within the uterus, based on animal and human models, has been estimated to be about 30 decibels, roughly consistent with the noise level in an average residence without a stereo on. Sounds are generated by maternal physiological processes (e.g., cardiac, digestive sounds, and placental sounds) and partially absorbed exterior noises. External sounds of high frequency generate greater intrauterine attenuation than low-frequency sounds. Prominent above this background is the partially altered, but distinguishable, maternal voice, which is conveyed both through internally conducted vibrations of the vocal chords as well as externally through the uterine wall. Fetal responses to auditory stimuli can be elicited as early as 24 weeks' gestation, suggesting that the fetus has a history of exposure to the maternal voice that is at least 4 months long.

Seminal work by DeCasper, Fifer, and colleagues provides the most convincing evidence for prenatal learning by examining whether newborn infants appear to recognize their own mother's voice. Although these studies are based on relatively small samples, and involve complicated methods to assess voice recognition in newborns, such studies indicate that fetuses do learn to discriminate their own mother's voice from that of another woman and prefer listening to their mother's voice. In addition, newborns prefer voices that are altered to reflect the acoustical properties as experienced in utero and voices that speak in their own language. Newborn infants can detect other maternal features, such as odor, suggesting that multidimensional maternal recognition that originates prior to birth may be adaptive for survival after birth. There is much less research on explicit efforts to expose fetuses to non-naturally occurring sounds in an effort to evaluate associative learning. There is evidence that fetuses can discern rhythmic variations in speech and musical stimuli detected by alterations in fetal behavior during stimulus onset. However, research on the ability of fetuses to learn specific musical segments as manifest by neonatal recognition is both preliminary and inconclusive.

The idea that exposing fetuses to auditory stimuli for the purpose of enhancing prenatal brain development or providing direct tuition in, for example, classical music or other patterned stimuli, is absolutely unsubstantiated by existing research. Although a number of commercial products for fetal stimulation are available for purchase, these are of dubious safety. In terms of efficacy, there is no credible scientific evidence that providing extra external stimulation to fetuses is beneficial, and a great deal of sentiment that it may in fact be harmful. Because fetal hearing is relatively mature, and the basal uterine environment relatively quiet, deliberate exposure to loud sounds may, at best, interfere with normal sleep–wake cycles and, at worst, may harm fetal hearing. The intrauterine environment is exquisitely tuned to maximizing development of the fetal brain and nervous system and there is no compelling reason to expect that disturbing normal ontogeny would provide benefit to it. In fact, evidence from animal models suggests that providing prenatal sensory stimulation beyond what is typically encountered for a species can result in interference with normal development.

Factors That Influence Fetal Development

Developmental Discontinuity

Although there are progressive linear changes in heart rate, motor activity, state development, and sensory/interactive capacities over the course of gestation, the trajectory of these changes shifts at a specific gestational period. Such shifts, or periods of discontinuity, are common during infant and child development and connote a period in which there is a qualitative shift in one or more domains. The first commonly recognized discontinuity occurs in the third month after birth, at which time infants become more interactive and progress beyond newborn behavior patterns. With respect to the development of fetal behaviors, the period between 28 and 32 weeks' gestation has emerged as a transitional period for maturation prior to birth. The discontinuity can be generalized as follows: prior to 28–32 weeks, the fetus displays immature neurobehavioral patterns with a relatively steep developmental slope; after 32 weeks, the trajectory of development becomes significantly less steep. In some ways, a fetus that has passed this transition is more similar to a newborn than to an immature fetus. These observations encompass most fetal parameters that change over gestation, including heart rate patterns, motor activity, fetal movement–heart rate coupling, fetal breathing motions, and responsivity to stimuli. The onset of these trends coincides with a period of rapid increase in neural development and myelination. This suggests that prenatal brain development toward the end of pregnancy is somewhat overdetermined and may serve as a protective mechanism for early birth. Support for this position is provided by the ultimate developmental and cognitive success of pre-term infants who are born after this gestational period.
period, despite immaturity in other organ systems. This is not to imply that development ceases after this period, or that certain aspects of fetal neurobehavior do not continue to develop in a linear fashion. For example, there is a linear increase in periods of wakefulness for fetuses that are post-term. However, at the very least, decelerative trajectories indicate that the rate of fetal maturation peaks early in the third trimester and begins to taper off well before term.

**Fetal Congenital Anomalies and Pregnancy Risk Factors**

If fetal neurobehaviors reflect the developing nervous system, it would be expected that factors with known neurotoxicity or that jeopardize normal pregnancies would also affect expression of fetal neurobehavior. Indeed, fetuses afflicted with a variety of chromosomal anomalies or malformations, including Down syndrome and neural tube defects, show variation in normal fetal development. This includes fetuses whose physical growth is proceeding below normal limits (i.e., intrauterine growth restriction). Exposure to a variety of potential teratogens (including alcohol, nicotine, methadone, and cocaine) has also been shown to affect various aspects of normal behavioral development. Fetuses of women with conditions that threaten pregnancy and change fetal growth, such as diabetes, exhibit differences in development, in this case presumably due to alterations in glucose metabolism and availability. However, despite the potential for detection of fetal compromise, the field is not sufficiently advanced to be able to predict poor developmental outcomes after birth based solely on detection of atypical patterns of fetal neurobehavior.

**The Maternal Context**

The psychological bond between mother and child has been extolled throughout history and literature but there is relatively scant scientific information on the inception of this relationship prior to birth. Whereas the knowledge base concerning neurobehavioral development is quite broad because it has been a subject of investigation for over 25 years, information on the maternal–fetal interface is quite new and much of it requires additional replication and scientific investigation. There are no direct neural connections between the mother and the fetus. Thus, to affect the fetus, maternal psychological functioning must be translated into physiological effects. This translation may occur through a number of processes, including direct transmission of neuroendocrines to the fetus through the placenta, alterations in maternal blood flow that affect levels of oxygen and nutrients available to the fetus, or changes in the intrauterine milieu that the fetus may detect through sensory channels.

Fetal behavior exhibits circadian rhythms. For example, fetal heart rate is lowest in the early morning hours and fetal motor activity peaks in the evening. However, during daytime hours, there are no consistent peaks or valleys of fetal activity or inactivity. It is unclear how or whether maternal diurnal patterns contribute to the observed fetal variations. Most information on whether maternal states influence the fetus has been generated by studies that monitor the fetus during periods of maternal arousal, induced through either physical exertion, including exercise, or mild psychological stress. Both have been associated with subtle alterations in fetal neurobehavioral functioning during the period of exposure.

There are a few studies that attempt to correlate maternal psychological attributes or experiences, including anxiety and stress perception, with fetal neurobehavior and longer-term outcomes in children. This interest has been sparked by evidence from animal models suggesting that chronic stress during pregnancy interferes with prenatal brain development in a manner that generates persistent and deleterious effects on postnatal development. However, to extrapolate these findings to assume that there must be similar effects on human fetuses may not be wise given the nature of how stress is conceptualized and measured.

In animal models, subjects are exposed to a series of experimental procedures that are controlled in terms of duration, frequency, and intensity. In contrast, human studies necessarily rely on measuring the elusive construct of psychological stress during pregnancy and then observing whether there are associations with child development years later. Maternal psychological distress before and after pregnancy are related, and there are well-known environmental influences of maternal distress on child rearing. Because what is measured in virtually all human studies of ‘stress’ during pregnancy is maternal affect and emotional responses to daily circumstances in women’s lives, it makes it difficult to know with certainty that there is a causal association and that other factors, including genetic mechanisms, are not involved. Moreover, the handful of studies that have detected deleterious effects of maternal pregnancy distress on developmental outcomes have yielded inconsistent and unreplicated results, including evidence of a paradoxical response of ‘accelerated’ postnatal development in children whose mothers reported moderately high levels of anxiety and stress.

When child development research was in its infancy, the common perception was that actions of parents in general, and mothers in particular, influenced the child. An influential paper by Bell in the 1960s introduced the concept of an opposite direction of effects: that parental behavior is directly influenced by characteristics and behavior of the child. Similarly, prenatal studies of development have focused on how pregnant women affect the fetus. Recent evidence indicates that the maternal–fetal link is also bidirectional. Specifically, fetal motor
activity in the second half of pregnancy stimulates episodic sympathetic surges in the maternal autonomic nervous system, even when women are unaware that the fetus has moved. Such maternal sympathetic activation by the fetus may serve as a signal function to the pregnant woman in preparation for the consuming demands of early child rearing. At the same time, pregnancy appears to result in maternal hyporesponsivity to environmental challenges; taken together these phenomena may serve to direct maternal resources away from less relevant environmental demands. As with postnatal maternal–child interaction, the best model for maternal–fetal interaction may be a transactional one, in which each influences the other in a dynamic cycle of reciprocity, but there is much to be learned in this regard.

**Continuities from Fetus to Child**

Investigation of normative development during gestation has been the focus of most of the research to date. The study of individual differences in fetal functioning and implications for predicting to postnatal development has been largely relegated to clinical applications. The progression from an age-based focus to interest in individual differences among fetuses parallels that observed in infant research. Do individual differences begin before birth? The presumption is that because there is wide variability in neurobehavioral development at birth, this range of individuality must begin prior to birth. There is good evidence that fetal neurobehaviors are relatively stable within individuals over time during gestation, thereby satisfying a primary requirement in their establishment as an individual difference. Unfortunately, there are not enough scientific investigations in which fetal neurobehavioral measures are examined in relation to child developmental or temperamental outcomes to be utterly conclusive. It is difficult to design such studies because the nature of the measures of specific domains of function as well as the methods needed to measure them are quite different in fetuses and children. However, those that have been undertaken reveal that there are basic continuities between fetus and child. These studies fall into two categories: those that attempt to document within-domain consistency between similar aspects of function, and those that investigate cross-domain predictiveness. The latter category presupposes that there is conservation of rank ordering across individuals from the fetal to infant periods on specific dimensions. Some degree of within-domain individual consistency spanning from the fetus to young child has been found for heart rate and variability, motor activity, and state control. This means that fetuses with faster heart rates have faster heart rates in childhood; more active fetuses tend to be more active toddlers; and fetuses that spend more time in quiet sleep tend to spend more time in this state in infancy. Cross-domain predictions are based on the consideration that some fetal measures are markers for general nervous system development, and as such, should have predictive validity to later aspects of functioning that have similar neural underpinnings. These studies have focused on the associations between fetal neurobehavior and either subsequent infant temperament or developmental proficiency. There is some evidence that fetuses with greater heart rate variability and coupling between movements and heart rate show more mature developmental outcomes in the first few years of life, and there is a suggestion that fetal heart rate and motor activity predict infant irritability and attentional performance. The current state of knowledge regarding the genesis and measurability of stable individual differences during the prenatal period is based on modest, single study findings that await replication and extension. Nonetheless, there is both strong theoretical support as well as modest empirical support that the fetus is indeed the precursor to the child.

**Conclusions**

The origins of development begin during the fetal period. Recent technological advancements have opened a window to this period of ontogeny that has resulted in an expanding field of inquiry. Substantial information exists to support the developmental progression of a range of fetal neurobehaviors over the course of gestation. Less is known about the manner in which individual differences arise and are conserved after birth, and the ways in which characteristics of the maternal and intrauterine environments affect the fetus, and how the fetus may, in turn, affect these contributors to its own development. However, there is little doubt that the period before birth sets the stage for the entirety of human development.

**See also:** Auditory Development and Hearing Disorders; Birth Complications and Outcomes; Critical Periods; Habituation and Novelty; Newborn Behavior; Physical Growth; Premature Babies; Prenatal Care; Screening, Prenatal; Teratology.

**Suggested Readings**

Preschool and Nursery School

H H Raikes, C Edwards and J Jones-Branch, University of Nebraska–Lincoln, Lincoln, NE, USA

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Glossary

Asili nido – ‘Safe nests’, the Italian term for infant–toddler centers.
Barnehage – ‘Children’s gardens’, care and education programs for children aged 0–3 years, in Norway.
Early childhood programs for children of age 3 years and under – Federal and state-supported center-based programs, private nursery schools, home visiting programs with a child development emphasis, out-of-home-enrichment programs for children, and 0–3 programs that originated in countries other than the US.
Early Head Start – A variation of the federal Head Start program for children in poverty under the age 3 in over 700 US communities.
Ecole Maternelle Francaise (EMF) – Publicly supported French nursery schools serving a third of French 2-year-olds.
Educare – High-quality 0–3 programs for children in poverty that blend funding from Head Start and other federal sources, states, localities and philanthropy, coordinated by the Bounce Learning Network.
Even Start – Parent–child literacy program.
Home visiting programs – Regular home visitor services offered in children’s homes to parents and children for purposes of enhancing children’s development. Examples of four programs are provided in this section.
Out-of-home enrichment programs – Educational programs for children under age 3 years that may also include instruction for parents. Several examples are included here.

Part C of the Individuals with Disabilities Education Act – A program that provides services for children under age 3 years with identified disabilities.

Introduction

This article provides descriptions of nursery education for children under the age of 3 years, including an overview of quality features for such programs, and descriptions of center-based, home visiting, out-of-home enrichment programs, programs for 0–3 year olds that are identified with other countries. It concludes with an overview of extant research on the effects of early childhood programs for 0–3 year olds.

Overview of Early Childhood Programs

Early Childhood Education (ECE) programs are highly prevalent in the US and in European countries, and are growing in emphasis in other parts of the world today. Children under age 3 years participate in group or formal educational experiences for a variety of reasons: (1) social and cognitive preparedness for preschool or formal schooling or enrichment; (2) remediation or intervention; (3) to learn specific skills deemed important by parents; or (4) for childcare in order for parents to work or pursue training. ECE for children age 3 years and under (sometimes referred to as nursery, crèche, or infant–toddler programs)