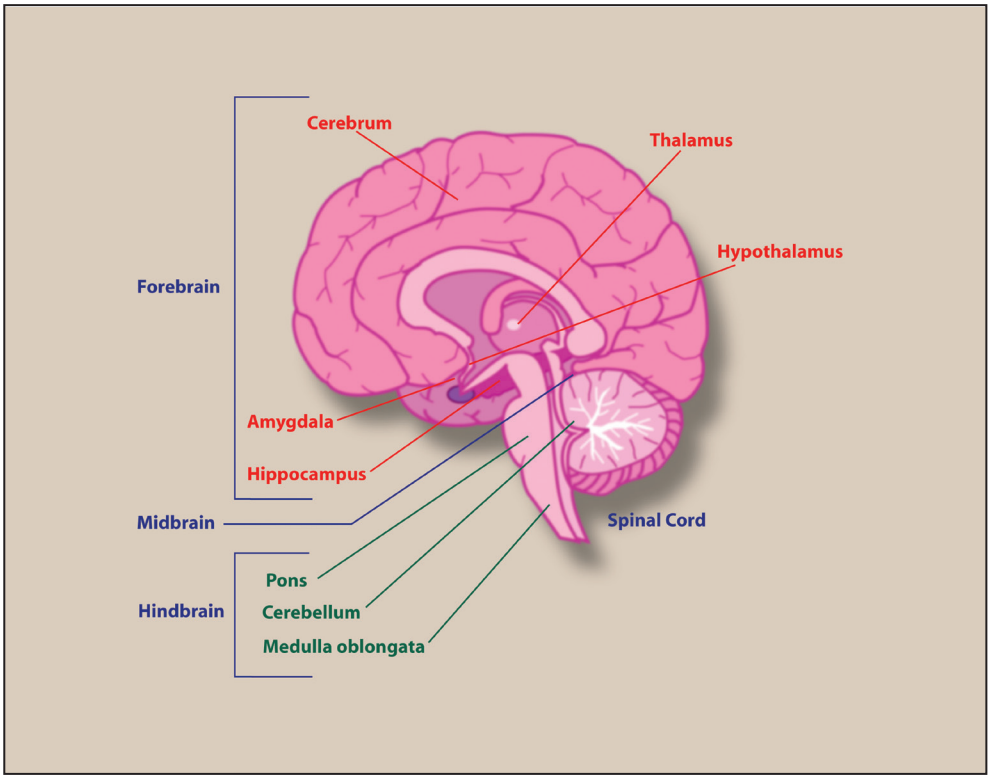
From Conception to Age Three: Building the Brain

The Urban Child Institute (TUCI) focuses on children from conception to age three because it is during this period that 80 percent of human brain development occurs. Many people assume that development of the brain does not begin until birth. *It begins at conception*, and the nine months in utero is a critical period for brain development. The following is a brief description of what is known about human brain development and why this earliest period is the foundation that influences the rest of an individual's life.

Figure 1: Brain



Source: http://www.educarer.com

Development of the central nervous system begins in the first trimester.

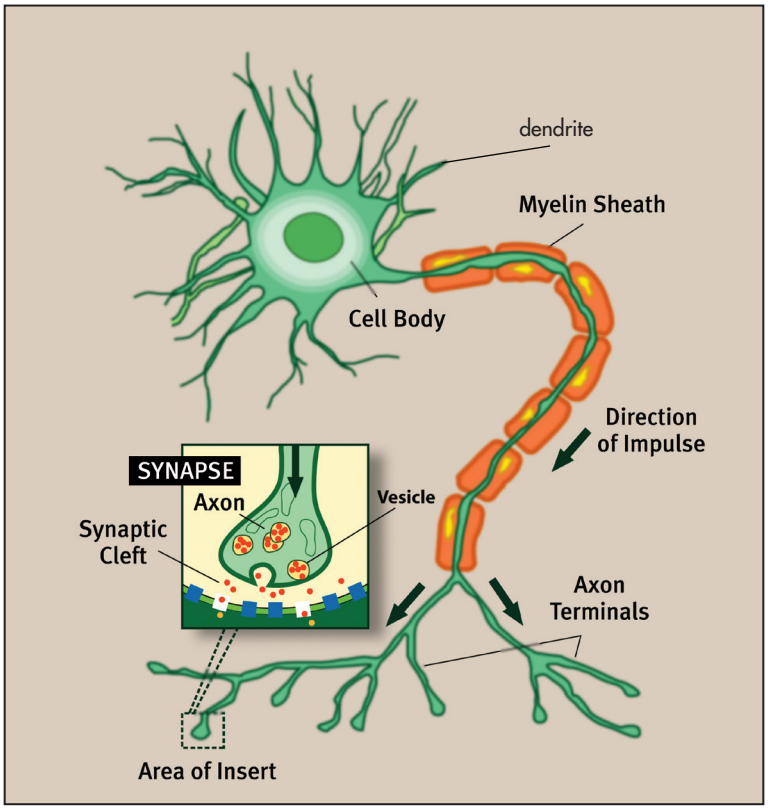
The central nervous system consists of the brain and the spinal cord. The spinal cord matures first, then the lower brain, or brainstem. Finally, the thinking part of the brain, known as the cerebral cortex, develops.

The nervous system begins to develop immediately following conception. The *neural tube* forms from the neural plate which appears by 16 days after conception. By 27 days the neural tube has closed and begun to transform into the brain and spinal cord of the embryo.

If the neural tube fails to close at the upper end of the embryo, the baby may be born without its cerebral cortex and with only a very rudimentary brainstem. This condition is known as *anencephaly*, and it is not compatible with life. If the neural tube fails to close at its lower end, a condition known as *spina bifida* occurs. In this situation part of the spinal cord may develop outside the spine and can be easily damaged.

Fortunately, if a mother takes folic acid in the first few weeks of pregnancy the possibility of neural tube defects is greatly reduced.

Figure 2: Nerve Axon



Source: http://www.educarer.com

About five weeks after conception nerve cells known as *neurons* begin to develop connections in the fetal spinal cord. The connections between these neurons are called *synapses*. By the sixth week these early neural connections allow the fetus to make its first movements, which can be detected by ultrasound. More coordinated movements develop over the next several weeks even though most women can not detect fetal movements until about 18 weeks.

Critical reflexes develop during the second trimester.

The brainstem connects the spinal cord with the upper brain. During the second trimester of pregnancy the brainstem begins to control many of the most critical reflexes. These include sucking and swallowing reflexes, control over heart rate and blood pressure, and development of the rhythmic contractions of the diaphragm and chest muscles necessary for breathing.

Most of these functions are operating by the end of the second trimester, and it is at this time that babies first become viable.

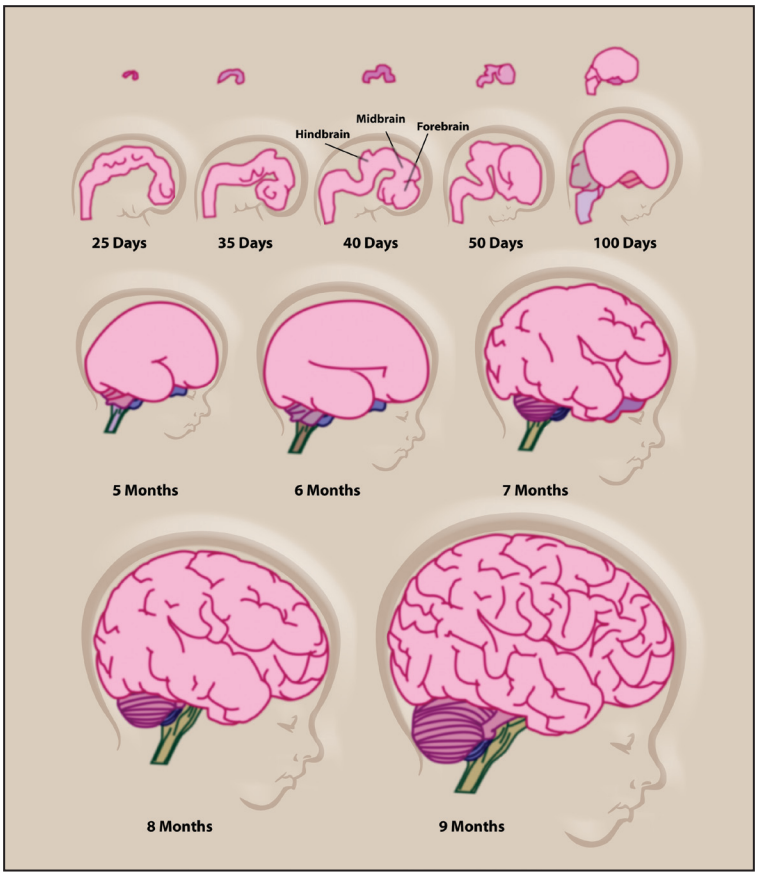
Feelings, memory, and thought are already at work in the third trimester.

The cerebral cortex is the portion of the brain that is responsible for higher brain functions such as feelings, memory and thought. It is the final part of the central nervous system to develop. Fetuses in the third trimester can demonstrate primitive learning. They can also respond to sounds such as a mother's voice.

Fetuses can be affected even by what occurs outside the womb. They can be affected positively or negatively by the levels and tones of voices, music and other sounds.

A newborn has most of its neurons at birth. Yet it is only after birth that the cerebral cortex begins to show its remarkable ability to assimilate and integrate the complex set of stimuli that the newborn and young child faces in the first years of life.

Figure 3: Development of the Human Brain



Source: Goldowitz, D., "How do you make a brain and keep it working?" University of Tennessee Health Science Center

During the first year of life an infant's brain has up to one trillion synapses.

The brainstem controls most of the earliest activities of a newborn such as crying, sleeping, grasping, sucking, rooting and primitive reflexes. Thus most of the basic instincts and reflexes necessary for survival are already operating at birth. The cerebral cortex is somewhat "loosely wired" but is prepared to become "hard-wired" in the next few years.

A few facts about what goes on in the cerebral cortex in utero and the first few years of life demonstrate the incredible potential of a newborn. Among these are:

- By four to five months of gestation the fetus has 100 billion neurons.
- Neurons are being created at the rate of 250,000 per minute.
- The brain is being "wired" as the neurons develop connecting synapses.
- Within eight months after birth the infant brain may have as many as 1 trillion synapses.

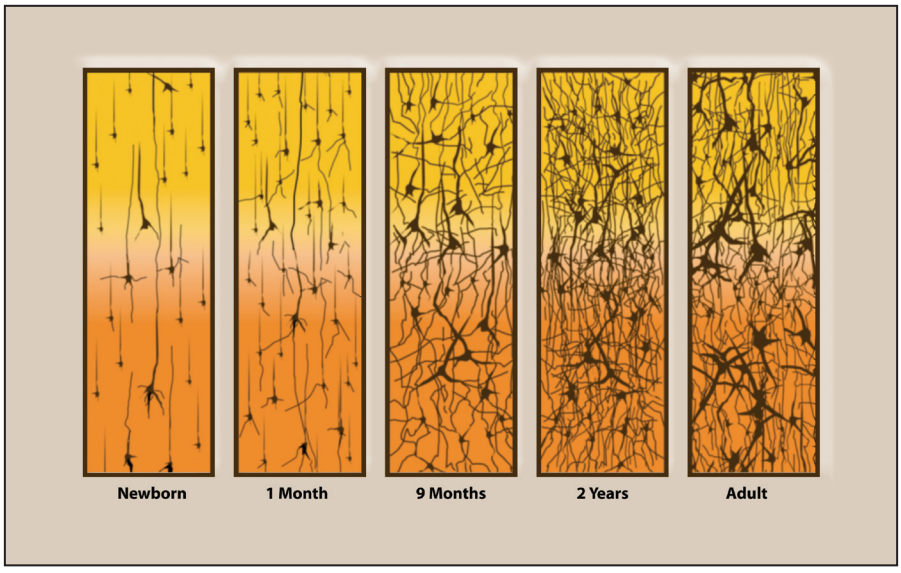
By age ten, a natural pruning process has reduced the number of synapses to about 500 billion, which is approximately the number of synapses found in the adult brain.

All senses enhance the development of synaptic connections within the young brain. These include:

- Touch/feeling
- Sound
- Vision
- Taste
- Emotional expressions
- Smell

The pruning process is determined, in part, by a "use-it-or-lose-it" phenomenon. Synapses that are being used persist. Those that are not stimulated disappear.

Figure 4: Development of Neurons and Synapses



Source: Corel, J.L.(1975) The postnatal development of the human cerebral cortex. Cambridge, MA: Harvard University Press

Early brain messages are critical.

A stimulated neuron sends a message electrochemically down its long tail (known as an *axon*). *Dendrites* branch off of the neurons and allow communication among neurons. Signals are sent across synapses through chemical neuro-transmitters. When a dendrite receives these signals it translates them into electrochemical messages, and the entire process is repeated through multiple neurons.

The earliest messages that the infant brain receives have an enormous impact. Parents and other care-givers play critical roles in helping to stimulate these infant brains with the right messages. Loving, looking into a baby's eyes, touching, talking, singing and repeating the sounds and facial expressions of the infant all provide an ideal stimulus for an infant's growing brain.

The level of exposure to language is crucial in the overall cognitive development of a young brain.

Language content also plays an important role. Research studies demonstrate that impoverished children hear two negative statements for each positive statement. Children from families in which both parents are professionals hear six positive statements for each negative. Scientists believe that differences in the number and types of words to which young children are exposed have a major impact on school readiness.

By age four a child of professional parents typically has heard 45 million words. A four year old in an impoverished family will have heard, on average, 12 million words.

Myelination allows hard-wiring of the brain.

Besides synapse formation and pruning, the other important post-natal event in the developing brain is known as *myelination*. Myelination represents a biological insulation that covers the brain cells and enhances the efficiency of the electrical transmission of signals along and among the neurons. It allows for much faster processing of information and accomplishment of more complex mental tasks.

Most myelination occurs in the first two or three years of life, but some may continue into early adult life. Myelination promotes the hard-wiring of the brain.

The brain can generate new neurons and synapses well into adulthood, but only at a fraction of the rate of the youngest years. It is in these earliest years that the brain demonstrates its greatest plasticity.

Stress can hinder brain development.

Most of an individual's neurons develop in utero. The post-natal growth of the brain is largely due to the development of synapses, the myelination process and the post-natal proliferation of the other principal brain cell known as the *glial cells*. These cells provide the scaffolding for the neuronal network. They also produce myelin and are involved in host defense and inflammatory responses in the central nervous system.

Severe emotional and psychological deprivation may cause a child's brain to develop to only 70 to 80 percent the size of a normal child's brain.

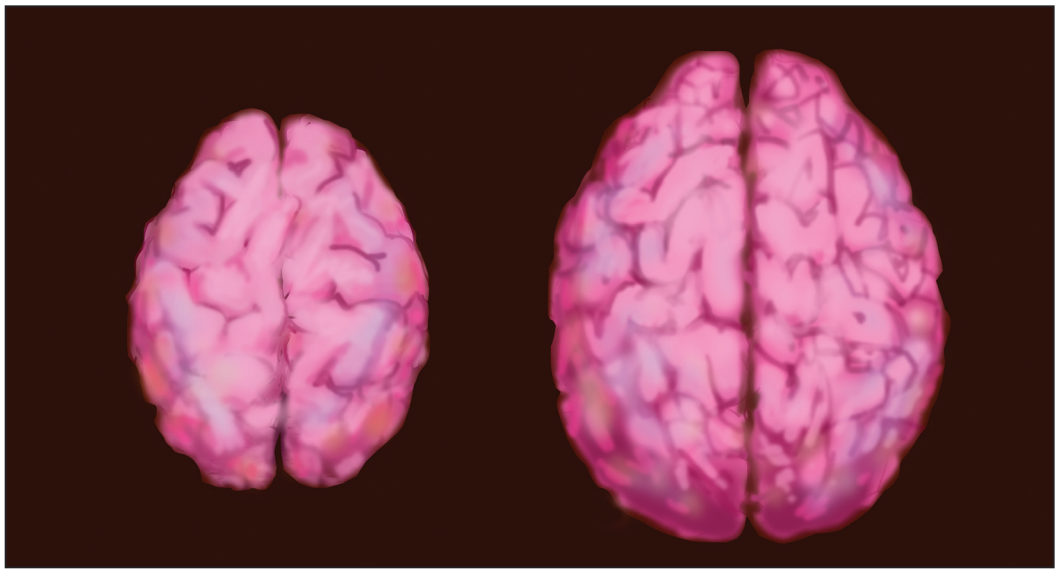
Chronic negative stress can produce elevated levels of the hormone cortisol that can have an adverse effect on brain development. Among factors thought to produce negative stress in young children are:

- Extreme poverty
- Emotional or physical abuse
- Serious threats
- Repeated exposure to violence

Excessive alcohol use during pregnancy can have severe effects on fetal brain development.

Fetal Alcohol Syndrome is the most common, preventable cause of mental retardation in America. Figure 5 shows severe damage to the brain of a five-day-old infant whose mother consumed large amounts of alcohol during pregnancy. The brain on the right in Figure 5 is normal.

Figure 5: Brain Damaged Pre-natally by Alcohol and Normal Brain



Source: http://www.isoa.org

Both nature and nurture contribute to brain development.

Genes (nature) determine when, where and how many brain circuits are formed, and the infant's environment (nurture) then shapes how those circuits are stimulated and used.

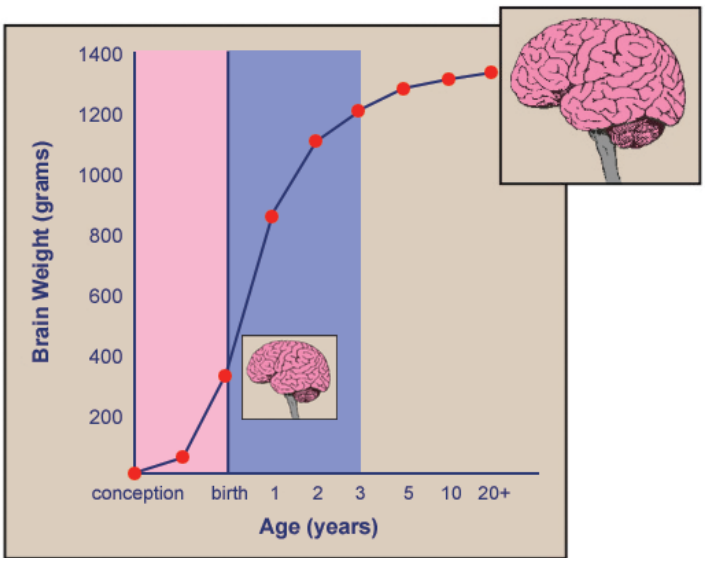
Research demonstrates the impact that early positive interventions have on the outcome of children. Studies show a positive return in education and employment achievement, as well as decreased cost to society in terms of lower rates of incarceration and reduced need for special education and welfare.

Furthermore, these same studies have demonstrated that the most impressive effects of such interventions are on those children who are at highest risk.

Nutrition is critical during the first months of life.

Good nutrition supports the growth of the brain's network of neurons throughout childhood. While formula offers an adequate alternative, there is ample evidence that breast milk provides the optimal nutrition for newborns. In addition to the well established psycho-social, economic, environmental and health benefits associated with breast-feeding, there appears to be a link between breast-feeding and enhanced brain development. The reasons remain controversial, but many researchers believe that chemicals in breast milk encourage brain development.

Figure 6: Brain Weight over Time



Source: Falk, D. (2007). Evolution of the Primate Brain. In W. Henke & I. Tattersall (Eds.), Handbook of Palaeoanthropology, 2 (pp. 1133-1162). Springer-Verlag

Brain Glossary

Neuron - A nerve cell.

Axon - The tail of a neuron.

Synapse - The region where communication between nerve cells occurs.

Anencephaly - A condition where a fetus fails to develop the cerebral cortex.

Spina bifida - A condition where a portion of the spinal cord develops outside the spinal canal.

Neural tube - Embryologically the earliest form of the nervous system.

Dendrites - Branches from a neuron that are involved in the transmission of electrochemical signals.

Myelination - The process in which nerve cells are insulated with a substance known as myelin. The result is improved efficiency of nerve signal transmissions

Glial Cells - Brain cells that serve as scaffolding for and support the growth of neurons

Fetal Alcohol Syndrome - A condition that may result in mental retardation of infants born to mothers who consume excessive alcohol during pregnancy