From conception to Age 3: Building the brain

The Urban Child Institute (TUCI) focuses on children from conception to age 3 because it is during this period that 80 percent of the human brain develops. 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. 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.

updated 12/3/2008

Brain

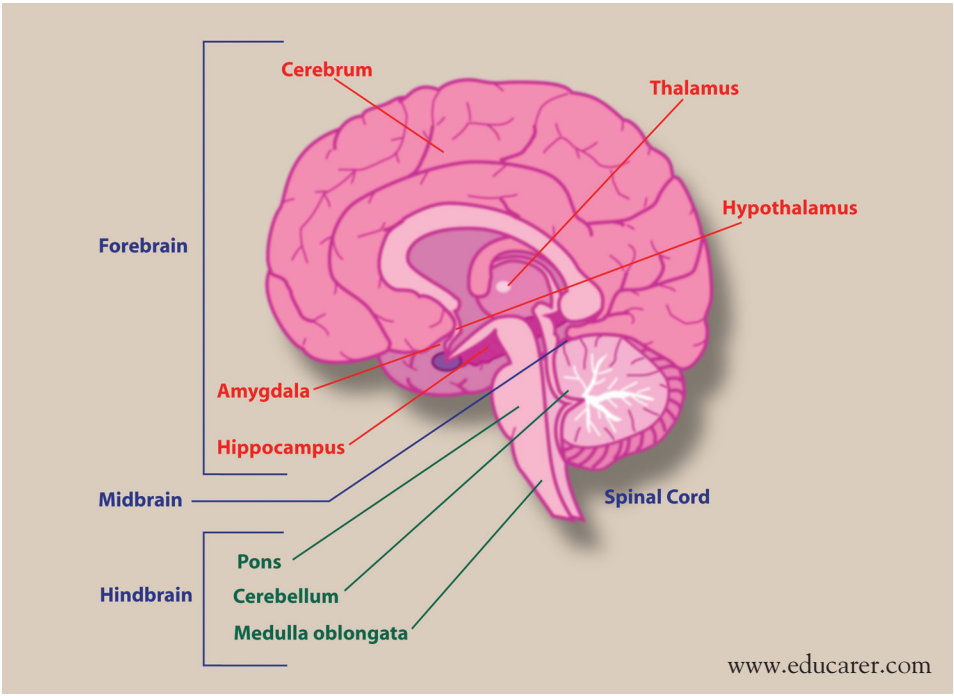


FIGURE 1

First trimester in utero: The central nervous system

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 only a very rudimentary brainstem. This condition is known as *anencephaly*, and is fatal. 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 be subject to damage easily.

Mothers can now take folic acid in the first few weeks of pregnancy and significantly reduce the possibility of neural tube defects.

Nerve Axon

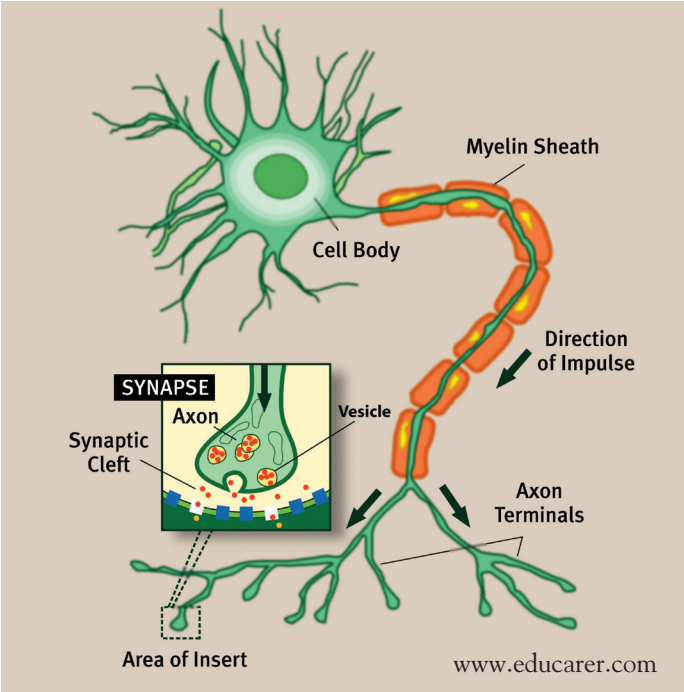


FIGURE 2

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.

Second trimester in utero: The brainstem

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, breathing and blood pressure and development of the rhythmic contractions of the diaphragm and chest muscles. These contractions become the basis of 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.

Third trimester: Cerebral cortex

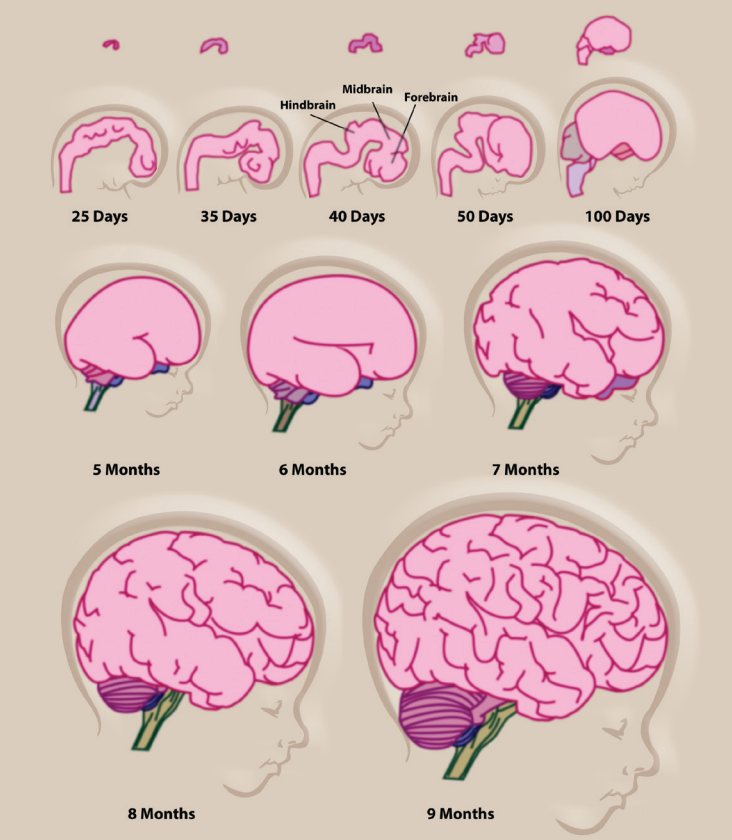
The cerebral cortex is the portion of the brain that is responsible for higher brain functions such as feelings, memory and thought. It is the final part of the central nervous system to develop.

Fetuses in the third trimester can demonstrate primitive learning. They can respond to certain sounds such as a mother's voice, for instance.

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.

Development of the Human Brain



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

FIGURE 3

Year One after birth

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 already are 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 1,000 billion synapses.

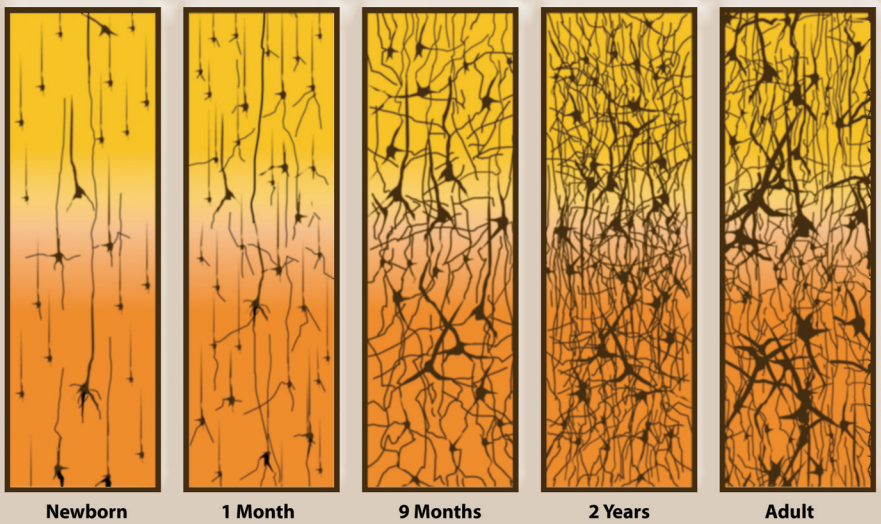
A natural pruning process reduces the number of synapses to about 500 billion by age 10 which is approximately the number of synapses found in the adult brain.

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.

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

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

Development of Neurons and Synapses



Conel, JL. The postnatal development of the human cerebral cortex. Cambridge, Mass: Harvard University Press, 1959

FIGURE 4

Early brain 'messages' are critical.

A stimulated neuron sends a message electrochemically down its long tail (known as an axon). Dendrites branch off the axon and connect with each other creating synapses. 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.

By age 4 a child of professional parents typically has heard 45 million words. A 4-year-old in an impoverished family will have heard, on average, 12 million words.

Language content also plays an important role. Research studies have demonstrated that impoverished children heard two negative statements for each positive statement. Children from families in which both parents are professionals heard 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.

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 "hard-wiring" of the brain.

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

The brain's glial cells

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 most 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

Brain damage from pre-natal alcohol

Excessive alcohol consumption by a pregnant woman can have a very deleterious effect on fetal brain development. **Fetal Alcohol Syndrome is the most common, preventable cause of mental retardation in America.**

The figure below shows severe damage to the brain of a five-day-old infant whose mother consumed large amounts of alcohol during pregnancy. The brain at right is normal.

Brain Damaged Prenatally by Alcohol Normal Brain

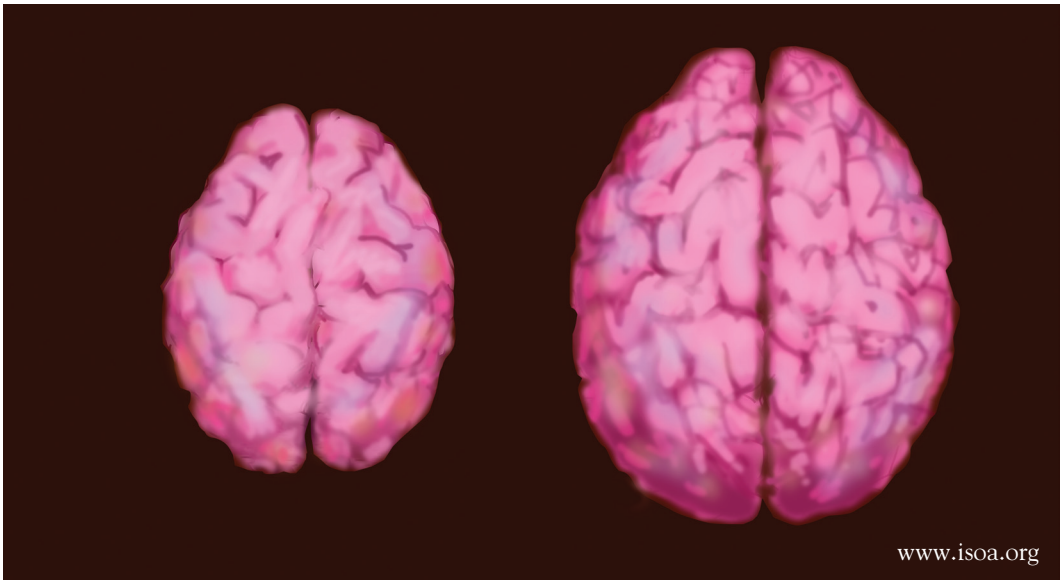


FIGURE 5

Nature vs. Nurture

Both nature and nurturing contribute to brain development. The two influences work together to produce the final product. Genes (nature) determine when, where and how many brain circuits are formed. The infant's environment (nurture) then shapes how those circuits are stimulated and used.

Data from many studies, mainly involving relatively small numbers of young children, demonstrate the impact that early positive interventions have on the outcome of children. These studies demonstrate a very positive return in education and employment achievement, as well as decreased cost to society in terms of lower rates of incarceration, and need for special education and welfare.

These same studies have demonstrated the most impressive effect on those children who might be considered at highest risk.

Nutrition in the first months of life

Good nutrition is critical to supporting 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 numerous health benefits associated with breast-feeding, it appears there is 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. Unfortunately, despite its numerous benefits, breast-feeding rates in Shelby County are among the lowest in Tennessee.

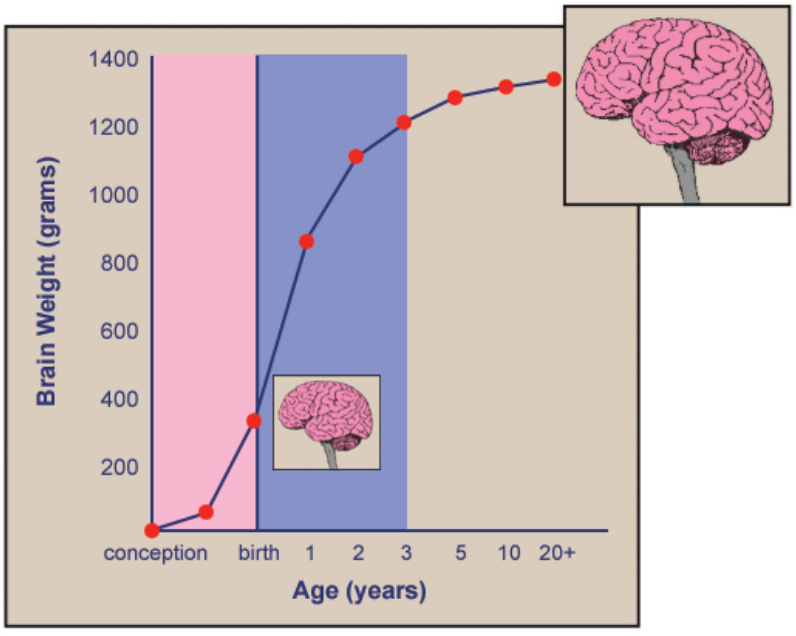


FIGURE 6

Summary

Positive interventions from conception through the first three years of life have measurable impacts on brain development.

TUCI believes that an investment in early childhood pays positive dividends over a lifetime. This is particularly true for young children considered at greatest risk. Addressing the existing the inequalities in Memphis and Shelby County is not only a practical investment in the community's future but a moral issue as well.

It is the institute's commitment to become the primary resource for objective data about children in our city and county in order that better decisions are made about where and how the community should invest so that every child has a running start to success.

Glossary

Neuron – A nerve cell.

Axon – The tail of a neuron.

Synapse – The region where communication between nerve cells occurs

Dendrite – A branch off the axon of a nerve cell

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 a 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