Frequently Asked Questions

Brain Development

The human brain begins forming very early in prenatal life (just 3 weeks after conception), but in many ways, brain development is a lifelong project. That is because the same events that shape the brain during development are also responsible for storing information—new skills and memories—throughout life. The major difference between brain development in a child versus learning in an adult is a matter of degree: The brain is far more impressionable (neuroscientists use the term *plastic*) in early life than in maturity. This plasticity has both a positive and a negative side. On the positive side, it means that young children's brains are more open to learning and enriching influences. On the negative side, it also means that young children's brains are more vulnerable to developmental problems should their environment prove especially impoverished or un-nurturing.

Q: Which plays a more important role in brain development, nature (genes) or nurture (environment)?

A: Genes and environment interact at every step of brain development, but they play very different roles. Generally speaking, genes are responsible for the basic wiring plan—for forming all of the cells (neurons) and general connections between different brain regions—while experience is responsible for fine-tuning those connections, helping each child adapt to the particular environment (geographical, cultural, family, school, peer-group) to which he belongs. An analogy that is often used is wiring a phone network: genes would specify the number of phones and the major trunk lines that connect one relay station to the next. Experience would specify the finer branches of this network—the connections between the relay station and each person's home or office.

For example, each of us is born with the potential to learn language. Our brains are programmed to recognize human speech, to discriminate subtle differences between individual speech sounds, to put words and meaning together, and to pick up the grammatical rules for ordering words in sentences. However, the particular language each child masters, the size of his vocabulary, and the exact dialect and accent with which he speaks are determined by the social environment in which he is raised—that is, the thousands of hours he has spent (beginning even before birth) listening and speaking to others. Genetic potential is necessary, but DNA alone cannot teach a child to talk.

Q: Does experience change the actual structure of the brain?

A: Yes. Brain development is "activity-dependent," meaning that the electrical activity in every circuit—sensory, motor, emotional, cognitive—shapes the way that circuit gets put together. Like computer circuits, neural circuits process information through the flow of electricity. Unlike computer circuits, however, the circuits in our brains are not fixed structures. Every experience—whether it is seeing one's first rainbow, riding a bicycle, reading a book, sharing a joke—excites certain neural circuits and leaves others inactive. Those that are consistently turned on over time will be strengthened, while those that are rarely excited may be dropped away. Or, as neuroscientists sometimes say, "Cells that fire together, wire together." The elimination of unused neural circuits, also referred to as "pruning," may sound harsh, but it is generally a good thing. It streamlines children's neural processing, making the remaining circuits work more quickly and efficiently. Without synaptic pruning, children wouldn't be able to walk, talk, or even see properly.

Q: How does nutrition affect the developing brain?

A: Brain development is most sensitive to a baby's nutrition between mid-gestation and 2 years of age. Children who are malnourished—not just fussy eaters but truly deprived of adequate calories and protein in their diet—throughout this period do not adequately grow, either physically or mentally. Their brains are smaller than normal because of reduced dendritic growth, reduced myelination, and the production of fewer glia (supporting cells in the brain which continue to form after birth and are responsible for producing myelin). Inadequate brain growth explains why children who were malnourished as fetuses and infants suffer often lasting behavioral and cognitive deficits, including slower language and fine motor development, lower IQ, and poorer school performance.

A baby's birth weight—and brain size—do depend on the quality of his or her mother's nutrition during pregnancy. Pregnant women should gain about 20% of their ideal pre-pregnancy weight (e.g., 26 lb for a 130-lb woman) to insure adequate fetal growth. This requires consuming an extra 300 calories per day, including 10–12 extra grams of protein.

After birth, brain growth depends critically on the quality of a child's nutrition. Breast milk offers the best mix of nutrients for promoting brain growth, provided that breast-fed infants receive some form of iron supplementation beginning around 6 months of age. (Most infant cereals are fortified with iron, and breast-fed babies require this supplementation at 6 months whether or not their mothers are iron-deficient.) Iron deficiency has been clearly linked to cognitive deficits in young children. Iron is critical for maintaining an adequate number of oxygen-carrying red blood cells, which in turn are necessary to fuel brain growth. Bottle-fed babies should receive formula that contains iron.

Because of the rapid pace of myelination in early life, children need a high level of fat in their diets—some 50% of their total calories—until about 2 years of age. Babies should receive most of this fat from breast milk or formula in the first year of life, and breast milk remains an excellent source of liquid nutrition into the toddler years. However, whole cow's milk can be introduced after the first birthday, and provides an excellent source of both fat and protein for toddlers in the second year. After 2 years of age, children should begin transitioning to a more heart-healthy level of dietary fat (no more than 30% of total calories), including lower-fat cow's milk (1 or 2%).

Q: How developed is the brain by birth?

A: Although it has already undergone an amazing amount of development, the brain of a newborn baby is still very much a work-in-progress. It is small—little more than one-quarter of its adult size—and strikingly uneven in its maturity. By birth, only the lower portions of the nervous system (the spinal cord and brain stem) are very well developed, whereas the higher regions (the limbic system and cerebral cortex) are still rather primitive.

The lower brain is therefore largely in control of a newborn's behavior: All of that kicking, grasping, crying, sleeping, rooting, and feeding are functions of the brain stem and spinal cord.

Even the striking visual behavior of newborns—their ability to track a bold moving object, like a red ball of string, or to orient to Mom or Dad's face—is thought to be controlled by visual circuits in the brain stem. When pediatricians conduct a series of reflex tests on the newborn, they are primarily assessing the function of these lower neural centers. These reflexes include the doll's eye maneuver (the baby's eyes stay focused forward when his head is turned to one side), the "Moro" or startle response (baby splays out arms and then slowly closes them in response to a sudden movement or feeling of falling), and even the remarkable stepping reflex (the baby "walks" when you hold him up with feet touching a flat surface).

The human brain takes time to develop, so nature has ensured that the neural circuits responsible for the most vital bodily functions—breathing, heartbeat, circulation, sleeping, sucking, and swallowing—are up and running by the time a baby emerges from the protective womb. The rest of brain development can follow at a more leisurely pace, maximizing the opportunity for a baby's experience and environment to shape his emerging mind.

Q: What role do parents play in a baby's brain development?
A: Parents are another important part of the developmental equation. Infants prefer human stimuli—your face, voice, touch, and even smell—over everything else. They innately orient to people's faces and would rather listen to a speech or singing than any other kind of sound.

Just as newborn babies are born with a set of very useful instincts for surviving and orienting to their new environment, parents are equally programmed to love and respond to our babies' cues. Most adults (and children) find infants irresistible and instinctively want to nurture and protect them. It is certainly no accident that the affection most parents feel toward their babies and the kind of attention we most want to shower them with—touching, holding, comforting, rocking, singing and talking to—provide precisely the best kind of stimulation for their growing brains. Because brain development is so heavily dependent on early experience, most babies will receive the right kind of nurturing from their earliest days, through our loving urges and parenting instincts.

In spite of all the recent hype about "making your baby smarter," scientists have not discovered any special tricks for enhancing the natural wiring phase in children's brain development. Normal, loving, responsive caregiving seems to provide babies with the ideal environment for encouraging their own exploration, which is always the best route to learning.

The one form of stimulation that has been proven to make a difference is language: infants and children who are conversed with, read to, and otherwise engaged in lots of verbal interaction show somewhat more advanced linguistic skills than children who are not as verbally engaged by their caregivers. Because language is fundamental to most of the rest of cognitive development, this simple action—talking and listening to your child—is one of the best ways to make the most of his or her critical brain-building years.

Q: Are there any differences in the development of boys' and girls' brains?
A: Yes, but they are subtle, and are a product of both nature and nurture.

Neuroscientists have known for many years that the brains of men and women are not identical. Men's brains tend to be more lateralized—that is, the two hemispheres operate more independently during specific mental tasks like speaking or navigating around one's environment. For the same kinds of tasks, females tend to use both their cerebral hemispheres more equally. Another difference is size: males of all ages tend to have slightly larger brains, on average, than females, even after correcting for differences in body size.

Electrical measurements reveal differences in boys' and girls' brain function from the moment of birth. By 3 months of age, boys' and girls' brains respond differently to the sound of human speech. Because they appear so early in life, such differences are presumably a product of sex-related genes or hormones. We do know that testosterone levels rise in male fetuses as early as 7 weeks of gestation, and that testosterone affects the growth and survival of neurons in many parts of the brain. Female sex hormones may also play a role in shaping brain development, but their function is currently not well understood.

Sex differences in the brain are reflected in the somewhat different developmental timetables of girls and boys. By most measures of sensory and cognitive development, girls are slightly more advanced: Vision, hearing, memory, smell, and touch are all more acute in female than male infants. Girl babies also tend to be somewhat more socially attuned—responding more readily to human voices or faces, or crying more vigorously in response to another infant's cry—and they generally lead boys in the emergence of fine motor and language skills.

Boys eventually catch up in many of these areas. By age 3, they tend to out-perform girls in one cognitive area: visual-spatial integration, which is involved in navigation, assembling jigsaw puzzles, and certain types of hand–eye coordination. Males of all ages tend to perform better than females on tasks like mental rotation (imagining how a particular object would look if it were turned 90 degrees) while females of all ages tend to perform better than males at certain verbal tasks and at identifying emotional expression in another person's face. (It is important to emphasize that these findings describe

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only the average differences between boys and girls. In fact, the range of abilities within either gender is much greater than the difference between the "average girl" and the "average boy." In other words, there are plenty of boys with excellent verbal skills and girls with excellent visual-spatial ability. While it can be helpful for parents and teachers to understand the different tendencies of the two sexes, we should not expect all children to conform to these norms.)

Genes and hormones set the ball rolling, but they do not fully account for sex differences in children's brains. Experience also plays a fundamental role. Consider, for example, the "typical" boy, with his more advanced spatial skills; he may well prefer activities like climbing or pushing trucks around—all of which further hone his visual-spatial skills. The "typical" girl, by contrast, may gravitate more toward games with dolls and siblings, which further reinforce her verbal and social skills. It is not hard to see how initial strengths are magnified—thanks to the remarkable plasticity of young children's brains—into significant differences, even before boys and girls begin preschool.

But this remarkable plasticity also provides parents and other caregivers with a wonderful opportunity to compensate for the different tendencies of boys and girls. For example, it is known that greater verbal interaction can improve young children's language skills. So the "typical boy" may especially benefit from a caregiver who engages him in lots of conversation and word play. On the other hand, the "typical girl" may benefit more from a caregiver who engages her in a jigsaw puzzle or building a block tower—activities that encourage her visual–spatial integration. The point is not to discourage children from sex-typical play (since pushing trucks or playing with dolls are great activities for any young child), but to supplement those activities with experiences that encourage the development of many competences.

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