How the Mind Grows from Conception to College

WELCOME TO YOUR CHILD'S BRAIN

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BLOOMSBURY

NEW YORK • BERLIN • LONDON • SYDNEY

THE BRAIN THAT BUILDS ITSELF

Moms and dads ask a lot of questions. My son says video games make him smarter—is that possible? How essential is it to breast-feed the baby? Is it okay to eat fish during pregnancy? Are vaccines safe for kids? My preschooler is writing her *R*s backward—is she dyslexic? And why can't I drag my teenager out of bed?

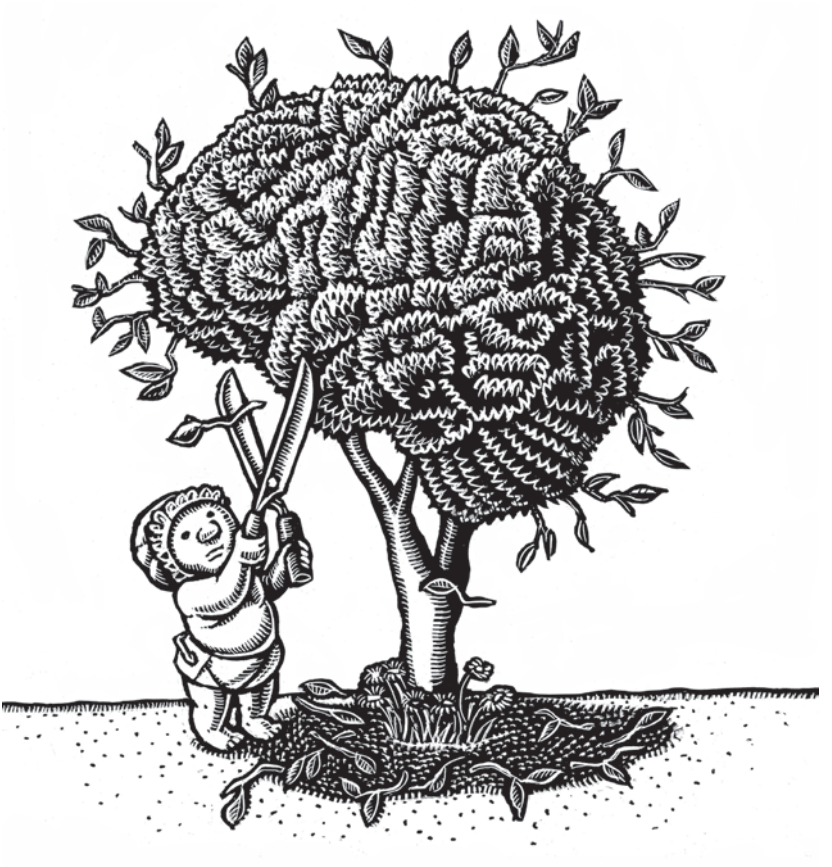
Call us geeks, but when we hear such concerns, we think about neuroscience. All of these questions involve the brain and how it develops. Childhood is a period of dramatic brain growth and behavioral change, and parents have a front-row seat. If you find this process as fascinating as we do, or if you're simply looking for some answers, this book is for you.

We cover the entire period from conception to college—because brain development goes on a lot longer than the first three years, where many other books stop. The growth and maturation of a child's brain is an intricate process taking decades, in which the brain grows and adapts to the surrounding world. The job won't be entirely finished until your child is in college. So whether your child is an infant, a toddler, or a teen, read on.

Between us, we have over forty years of experience as neuroscientists. Sandra started in the laboratory doing research on brain development and **plasticity*** and went on to edit one of the leading journals in neuroscience. She has read thousands of papers, many of them reporting pioneering discoveries. Her critical eye comes from having a view of the field that is both broad and deep. She knows when a result is sound and when it is fishy.

Sam is a professor and researcher at Princeton University. He has been publishing original research and teaching students for over twenty years. His own

*Bold terms are defined in the glossary. See pp. 267–273.



research concerns how the brain processes information and learns—and how this process can go wrong in early life.

Sam is also a dad. Before his daughter came along, he used to talk about what we called *cocktail party neuroscience*. Life changed for him, so now it's *preschool potluck neuroscience*. At these parties, parents and teachers ask lots of fun questions, but sometimes he's noticed a touch of anxiety as well.

Your questions sent us to the library. Together we scoured the technical literature, studying many hundreds of papers in neuroscience, psychology, medicine, and epidemiology. We synthesized this vast literature into our best interpretation of what is known about children's brains. This book is the result of all that research. In it, we explain the science, debunk myths, and include practical tips for you as parents.

Here's our first instruction: **take a deep breath and relax**. Really. The things

you're worrying about are much smaller factors in your child's well-being than you might imagine. Many modern parents believe that children's personality and adult behavior are shaped mainly by parenting—but research paints a very different picture.

There is a simple way to summarize much of the research on the neuroscience of child development: children grow like dandelions. In Sweden, the term *maskrosbarn* (**dandelion child**) is used to describe children who seem to flourish regardless of their circumstances. Psychological studies suggest that such children are relatively common (at least when raised by "good enough" parents who do not abuse or neglect them). From an evolutionary perspective, this makes sense; children who can make do with whatever time and attention their parents can spare are more likely to survive and pass along their **genes** under tough conditions. For many brain functions, from temperament to language to intelligence, the vast majority of children are dandelions.

Here's our first instruction: take a deep breath and relax. Really.

The developing brain has been shaped by thousands of generations of evolution to become the most sophisticated information-processing machine on Earth. And, even more amazingly, it builds itself. For instance, you do not need to teach your children to notice—and eventually produce—human speech. Your baby son or daughter knows, very early on, that the noises you make have more meaning than other sounds. So even if you never give your children a speech lesson, they are highly unlikely to start imitating the air conditioner or the family cat. At least not convincingly.

Children are not passive recipients of parenting or schooling, but active participants in every aspect of their own development. From birth, their brains are prepared to seek out and make use of experiences that suit their individual needs and preferences. For this reason, brain development requires no special equipment or training, and most children find a way to grow in whatever conditions the world has to offer them.

If children are so adaptable and smart, why can't they start using their brains for high-powered activities right away? In large part it's because the development process tunes each individual's brain to the characteristics of a particular envi-

ronment. This is one reason that people can live successfully all over the world. Genes provide the blueprints for your child's individuality, but the plans are certain to be modified during construction depending on local conditions—not only your actions as parents, but also your child's culture, neighborhood, teachers, and peers. This matching process is automatic, with some support from you along the way. All this leads us to the major theme of this book: **your child's brain raises itself**.

In a few circumstances, extra help is necessary. Things can go wrong if the genetic program has a flaw or if environmental conditions are very difficult, as happens in poverty or war. Modern life has also created some new challenges. Brain development can get into trouble when our modified environment fails to play nicely with our ancient genetic heritage. For these cases, we tell you how to give your child that extra boost.

We organized the book around seven scientific principles that will help you understand how your child's brain grows and changes along the path to adulthood.

• **Part 1, Meet Your Child's Brain.** This section is an introduction to your child's brain and how it works. In particular, we talk about how innate predispositions for interacting with the outside world initiate a two-way conversation between genes and environment that shapes neural development throughout childhood.

• **Part 2, Growing Through a Stage.** The brain goes through periods when it builds upon earlier foundations and is exceptionally sensitive to certain types of information. This section describes the experiences that your child's brain uses to shape the development of sleeping, walking, and talking.

• **Part 3, Start Making Sense.** Much of neural development relies on experiences that are easily available to almost any child. As parents, you get a free ride on this process; simply sit back and watch your child's senses tune themselves to the world.

• **Part 4, The Serious Business of Play.** One of the major ways that children adapt to their circumstances is through play. From preschool through adolescence,

play is practice for adult life and helps to develop some of the brain's most important functions.

• **Part 5, Your Child as an Individual.** Distinctive features of the genetic program make your baby a unique person from the start. Here we explain how your child's individual emotional and social characteristics grow and respond to the surrounding world.

• **Part 6, Your Child's Brain at School.** Most of the evolutionary history of our species happened before there were books, violins, or calculus—not to mention Facebook. We tell you how the flexibility of your child's brain allows her to handle abstract concepts that our ancestors never imagined.

• **Part 7, Bumps in the Road.** All environments present challenges to the developing brain. Most children can get what they need to grow, like dandelions, but a few are more delicate flowers needing extra care or attention. We explore what you can do to help your child if anything goes wrong.

Feel free to dip in anywhere that interests you. Headings indicate the age range that is the focus of each chapter, so that you can easily find out whether we have something to say about your child's brain, however old he or she is right now. As you can see, we've got a lot of ground to cover, so let's get started.

PART ONE

MEET YOUR CHILD'S BRAIN

THE FIVE HIDDEN TALENTS OF YOUR BABY'S BRAIN

IN THE BEGINNING: PRENATAL DEVELOPMENT

BABY, YOU WERE BORN TO LEARN

BEYOND NATURE VERSUS NURTURE

Chapter 1

THE FIVE HIDDEN TALENTS OF YOUR BABY'S BRAIN

AGES: BIRTH TO ONE YEAR

Your baby is smarter than he or she lets on. For generations, the slow development of **motor** systems led psychologists to believe that babies had very simple mental lives. In a baby who has not worked out how to walk or talk, mental capacities cannot be measured by approaches used to test grown-ups. But in the past few decades, scientists have figured out better ways of getting information from infants. With these new tools, researchers have shown that babies' minds are very complex right out of the box—as many parents suspected all along.

All brains, young and old, have certain broad talents that help their owners to navigate life successfully. If you look closely, you can already see many of these talents in your infant. Although babies lack knowledge, they are born with certain tendencies that influence how they organize incoming information and respond to it. They are predisposed to seek out experiences that will help adapt their growing brains to their particular environment. Or, to put it more simply, your child's brain naturally knows how to get what it needs from the world. For this reason, most brain development requires only a "good enough" environment (more on that later), which includes a reasonably competent (though not perfect) caretaker.

What do babies know and when do they know it? They can't tell us in words, but researchers can still ask babies questions and get sophisticated answers about their **cognitive** abilities. A few simple, nonverbal ways of looking into the minds

of infants and even newborns have revolutionized developmental psychologists' ability to tell what young babies think and feel.

Your infant isn't good at controlling most of her body, but she can suck on a nipple immediately at birth. Not long after that, she can turn her head and eyes to look at an interesting object or event. These two abilities can be used to find out what catches her attention. For example, if your infant likes an event that happened while she was sucking and wants it to happen again, she will suck more vigorously. Your newborn will suck harder when she hears a recording of her mother speaking, but less so when she hears another woman. This is how we know that, from birth, infants recognize Mom's voice.

Like adults, babies get bored. After your baby has looked at something for a while, he will turn away and look at something more interesting. Researchers

can observe how long a baby looks at a particular scene. If the scene contains something surprising to the baby, he will look longer.

This response allows us to find out whether a baby can tell the difference between two things. For example, if you show your baby a series of pictures of cats, the appearance of a dog will attract a long look. This means that babies can distinguish cats from dogs—a feat that is extremely difficult to program into a computer.

Simple tools like these enabled researchers to identify five brain talents that infants already have well before their first birthday.

The first talent: babies can detect how common or rare particular events are. For example, a first step in learning a language is figuring out which syllables go together to form a word. Yet when speaking, people tend not to pause between words. One way to learn words is to determine which syllables are likely to occur together. For example, when your baby hears the words *the baby* being spoken, how can she tell that it's the English word *the* followed by *baby*, and not the made-up word *theba* and then *by*? One clue is that *baby* is a far more common pairing of sounds than *theba*.

A well-designed experiment showed that in general, babies really do think this way. Researchers generated four nonsense words, such as *bidaku*, each composed of three syllables. They then presented these nonsense words to eight-month-old babies in varying order, without pauses between the words. Once the babies were familiar with these new words, the researchers then presented either one of the nonsense words or a new one composed from the original syllables (like *kudabi*). They let the babies control how long the words were played by looking in the direction of the speaker. The researchers found that babies listened significantly longer to the new words, even though the component syllables were the same. Since the babies had already heard all the syllables individually, the researchers concluded that they must have become familiar with the original groupings. This ability to detect the probability of events, shared by many animals, is a key component of learning. It provides the basis for answering important questions like "Where am I most likely to find food right now?"

The second talent: babies use coincidences to draw conclusions about cause and effect. After language develops, two-and-a-half-year-old children can make explicit causal statements like "He went to the refrigerator because he was hungry." But well before this, babies appear to be able to detect such relationships.

In one experiment, a mobile was hung over the crib of three-month-old babies and attached to one leg by a ribbon. When a baby kicked, the mobile would move. The babies were fascinated by this new toy. They smiled more and looked at the mobile more than they did when a similar mobile was out of their control. After just a few minutes of training, they kicked more. Three days later, they still kicked when they saw the first mobile (but not a different one), even when the ribbon was no longer tied to their legs. Since the kicking was a specific response intended to get the mobile to move, these babies seem to be learning an elementary form of cause and effect. Using events that occur together to determine possible underlying causes is a key part of our ability to learn how the world works.

Babies can distinguish cats from dogs—a feat that is extremely difficult to program into a computer.

The third talent: babies distinguish *objects* from *agents* and treat them very differently. Infants—like all other people—understand that objects are cohesive (all the parts of the object stick together), solid (something else can't go through an object), and continuous (all the parts of an object are connected to other parts), and only move when something touches them. For many years, it was accepted that infants under eighteen months did not understand *object permanence*, the idea that objects continue to exist even when you can't see them. This bit of popular wisdom, originally disseminated by the pioneering psychologist Jean Piaget, was recently challenged by researchers who found the right ways to test infants.

Well before their first birthday, infants look longer if an object fails to be cohesive, solid, continuous, or permanent. In one experiment, five-month-old babies saw a car roll down a track whose middle section was hidden behind a screen. When a boxlike obstruction was then placed on the track behind the screen, five-month-old babies appeared to expect it to stop the car. How do we know this? When researchers secretly removed the obstruction through a trapdoor, and the car continued to roll down the track successfully, the babies looked longer at the screen, suggesting that they were surprised that the box was not solid. When evaluated in this way, babies as young as three and a half months old show that they can think about objects that are out of view behind other objects.

MYTH: IF ANYTHING GOES WRONG, MOM IS TO BLAME

Sigmund Freud has a lot to answer for. His ideas were speculative and eventually discredited by further research, but they have left deep impressions on our culture. One of the most pervasive ideas is that a baby's relationship with his or her mother serves as a model for all later relationships in life. This idea has led many people to conclude that a mother's behavior has an incredibly strong influence on what kind of a person her child will later become. From this belief, a culture has arisen in which complete strangers feel a moral obligation to intervene if they see a pregnant woman having a sip of wine or a mother yelling at her young son. In the past, psychiatrists even blamed mothers for their children's autism or schizophrenia—both developmental disorders that are largely due to genetic mutations.

It's time to relax. Now that you know that children actively participate in their own development, it should be clear that parents do not need to be perfect. We don't recommend yelling, but that's mostly because it's an ineffective way to modify your child's behavior (see chapter 29), not because your occasional bad mood is likely to do any serious, lasting damage to his psyche. Anyway, as you'll see in chapter 17, parenting style has much less influence on personality than most of us believe. We'd like to see parents enjoying their kids more, rather than worrying over every aspect of their growth. That approach would be just as effective in producing healthy adults—and much more fun for everyone.

Babies also recognize agents, beings that have intentions and goals and can move on their own. Hands, for instance, always belong to agents. If six-month-old babies see a hand reaching for one of two objects, they seem to understand that the person wants that particular object. When the location of the objects is then reversed, the babies look longer if the hand reaches for the same location (but a different object) on the second try. If instead a stick pokes the object, babies don't act surprised when the stick fails to follow the object to a new location, because a stick is not expected to act like a conscious agent.

Like adults, babies are willing to attribute agency to things that are not really

alive. When watching a film of a circle that seems to be chasing another circle, one-year-old babies look longer if the first circle moves away from the second circle than they do if the first circle moves straight toward its presumed target.

The fourth talent: babies organize information into categories and people into groups. When infants as young as three months see a series of male faces, they spend less time looking at each new face, presumably because they're bored with looking at men. When a female face then appears, they look longer. This is true even if the hair is not visible, so the babies seem to be using facial features, not hairstyles, to distinguish men from women. These categories are relevant for babies' everyday lives. Most babies prefer looking at female faces to looking at male faces—except when their primary caretaker is male, in which case they are able to muster a slight preference for men.

Some broad categories like *animals* and *furniture* can be found very early in life; others are learned later. The boundaries of many categories, from the sounds of language to face perception, are shaped by experience to match your child's local environment. But no one ever has to teach babies that categorizing things is a good strategy; it's built into their brains. This ability provides a primitive basis for adult categorization, which makes it possible to think sensibly about newly encountered objects and people. It is also the root of stereotyping and prejudice, as we will see in chapter 20.

The fifth talent: babies select relevant information for attention while discarding most of what goes on around them. As you may have noticed, babies are much less selective than adults about what captures their attention, but they still have distinct, automatic biases. From an early age, babies focus a lot on human voices, faces, and moving things. Babies start showing this preference for faces at thirty minutes after birth, and for human voices two days later. After three months of age, they notice objects that look distinctly different from surrounding objects, such as a red circle in a field of black circles.

Very early on, caregivers begin to influence the direction of a baby's attention. Babies start to follow an adult's gaze as early as four months of age. By twelve months they can point and direct their attention where someone else is pointing. At all ages, paying attention greatly increases the brain's ability to learn about specific things. In computer models of brain function, innate biases in what information is given priority can provide a powerful mechanism for directing the learning of particular tasks. Babies' innate interest in voices, for example, helps

them to learn about language. All of these talents help babies' brains develop like dandelions, requiring only everyday types of stimulation that adults give normally—and instinctively.

In adults, these five talents are fundamental to the way our brains work. Indeed, in most of us these talents are inclined to be hyperactive. When we find ourselves considering our computers or our cars as if they had their own intentions and goals (typically in opposition to whatever we'd like them to do), our tendency to perceive agents is getting out of hand. When a baseball pitcher wins three games while wearing a certain pair of socks, and then insists on wearing his lucky socks whenever he plays, he is drawing conclusions about cause and effect from events that probably occurred together by chance.

There's a practical reason why many of our scientific examples come from three-month-olds: younger babies are harder to test. Based on the evidence we have, our own belief is that these capacities are present from birth, at least in some primitive form. In the end, though, we don't think it matters very much whether babies are born with these abilities or learn them soon after birth. Either way, babies start relying on these tools in infancy and continue to use them throughout their lives. On the other hand, these cognitive capacities are just the beginning. All of them become significantly more elaborate as babies grow and mature.

From an early age, babies focus a lot on human voices, faces, and moving things.

This emerging picture leaves little room for the outdated idea that babies are born with the potential to develop in any direction. Instead, they all start with certain biases. The cognitive talents that babies have in early life are essential for the development of their brains. Computer scientists who construct simulations to model what the brain does also confirm that biases are necessary to make these programs act realistically, even though our biases may limit us in some ways. They have not been able to explain convincingly how an adult brain might develop from a learning machine that starts with no predispositions.

As a consequence of these core talents, children's brains come ready to learn how to adapt themselves to the environment that they encounter during development. This ability allows children to grow almost anywhere. Our species

has survived under a wide range of conditions through its history, and we have evolved to learn about the properties of the environment that were directly relevant to our survival. For this purpose, targeted learning mechanisms are often better than general mechanisms. These predispositions prepare the infant brain to learn many things—but not just anything.

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