An insightful and practical guide that looks at the role neuroscience plays as it relates to the treatment of childhood and adolescent disorders

Written in an accessible way, Brain-Based Therapy with Children and Adolescents: Evidence-Based Treatment for Everyday Practice shows clinicians how they can become more effective therapists by understanding and applying recent findings about the brain in their work with children and adolescents. The result is a new kind of therapy, one that takes into account both the uniqueness of each child or adolescent, as well as the requirements of standardized care as recommended by evidence-based practice—offering mental health professionals advice they can put into practice immediately.

Relying on research in developmental neurobiology, brain imaging, and evidence-based psychotherapeutic practices, the authors, experts in both neuroscience and evidence-based practice, cover:

- The importance of understanding how the brain develops and functions in doing the actual work of child and adolescent psychotherapy
- Recent neuroscientific discoveries and how these can be integrated into evidence-based interventions to create uniquely effective treatments
- Evidence-based interventions for the most common childhood and adolescent disorders, such as ADHD, OCD, and depression
- Tips on helping children and adolescents re-regulate such neurodynamically important processes as sleep and the mind-body relationship

Incorporating useful vignettes that illustrate how to include these new treatments into effective client care, Brain-Based Therapy with Children and Adolescents: Evidence-Based Treatment for Everyday Practice explains the concept of brain-based therapy in a succinct and easy-to-grasp way, enabling therapists to make practical sense of neuroscience and how it can work within their daily practice.

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Brain-Based Therapy with Adults: Evidence-Based Treatment for Everyday Practice

John B. Arden and Lloyd Linford
Brain-Based Therapy with Children and Adolescents
Brain-Based Therapy with Children and Adolescents

Evidence-Based Treatment for Everyday Practice

By
John B. Arden
Lloyd Linford

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For our sons

Paul and Gabe Arden
and
Zack and Scott Linford
and
those who will share their future
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Although many excellent brains were involved in the creation of this book, only two are responsible for its errors and omissions.

—John Arden, Sebastopol, California
—Lloyd Linford, Piedmont, California
Preface

Helping children in trouble is an aspiration that is for the most part built into the brains and hearts of adults, and predates our origins as *Homo sapiens*. But as an actual *vocation* in the western sense, it is quite recent. The child-helping professions originated in 19th-century Europe and America. Urbanization and factory-based work left parents with less time for their families, and children were exposed to many new challenges and stressors. Cut loose from their religious and agrarian moorings, social values began to drift. Widespread literacy and compulsory education fueled the process of change. Not coincidentally, child psychiatry, psychology, and social work all originated in this period. Social work was born in the slums of London and New York, and child psychology’s roots go back to 19th-century Austria and France. Siegfried Bernfeld (1922), August Aichorn (1926/1955), and Anna Freud (Burlington & Freud, 1940; Freud, 1946) blended their devotion to children with fealty to Sigmund Freud.

The approaches used by Anna Freud and others had, of necessity, to take stock of the unique challenges of working with children. While doing psychotherapy with adult patients may allow us to forget how embedded each individual is in a social system, children never let us forget this fact. The psychological assessment of a child must include an evaluation of the psychological strengths and weaknesses of parents and siblings, of actual sources of anxiety, and of actual experiences of trauma and loss.

The works of these early social workers, marriage and family counselors, and child psychologists continue to constitute the core curriculum for all students of our art, yet they all leave something out. They all underplay the actual basis for child psychology: the developing brain. As we suggested in Volume 1 of this series, *Brain-Based Therapy with Adults*, the two greatest minds in nineteenth-century psychology, Sigmund Freud and William James, were talented and expert neurophysiologists. Yet both abandoned the biological study of the brain in favor of more theoretical pursuits about how the mind works. Freud’s “Project for a Scientific Psychology” (1895/1958) sets out the
aspirations shared by many psychotherapists today: to construct a theory of the mind (and therapy) that rests on solid biological evidence. Strangely, Freud never published the “Project” in his lifetime, whether because he had reservations about abandoning his work as a neurologist or for other reasons we will never know.

Understanding the neurobiology of attachment and relationships—how the brain insures the continuity of early patterns of relating and at the same time has the capacity for changing them—is basic to the new curriculum for child psychotherapists and pediatric residents. It is one thing to talk about this issue with adults, where therapists are preoccupied with brain changes that, in the developmental scheme of things, are more in the nature of a tune-up than a complete overhaul. It is another thing to look at the unfolding of the brain in children, where the changes are dramatic and ongoing. Children are exquisitely sensitive to the environment and change in relationship to it even before birth—and it is the brain that makes this apparent paradox of innate structure and almost infinite plasticity possible.

In our view, the most important development in psychology in the last decade is the emergence of attempts to synthesize developmental psychology, neuroscience, and psychotherapy. In the work of Schore (1994), Segal (1999), and Cozolino (2006), links have been made between the brain and the mind in psychodynamic therapy. Developmental pathology breaks new ground in taking a fundamentally integrative approach to the attachment literature of psychological theory (Cicchetti, et al, 2006; Sroufe et al., 2005). The biological approaches of Jerome Kagan and Mary Rothbart synthesize perspectives from the temperament literature and evolutionary biology (Kagan, 2004). Some long-standing theory-based observations—for example, Melanie Klein’s idea that parents have the capacity to project unconscious anger into their child, unconsciously identify with the anger, and then punish the child for aggressive behavior—suddenly makes sense on the biological as well as the clinical level (Klein, 1975/1921–1945). So far no one has attempted to apply these lessons specifically to working therapeutically with children in a broader psychological frame of reference. That is a goal of this book.

For most therapists, however, the big question is still “So what?” What difference will understanding how the brain develops and functions make in doing the actual work of child psychotherapy? How does this new knowledge relate to the ideas and clinical methods of such giants of child psychology as Anna Freud (Sandler & Freud, 1985), Piaget (1951), Winnicott (1941/1975; 1975), and Bowlby (1969)? What difference is it going to make when I next close the door and begin an hour with an
active and oppositional child? In this volume, we hope to answer these questions, and the answers we propose are encouraging in terms of how much of the traditional theory and technique are not just salvageable in the new neurobiological frame of reference, but actually clarified and put on firmer ground.

For child psychotherapists, developmental neuroscience currently has an importance comparable to the role of the frontier in 19th-century America. Horace Greeley, a newspaperman of that period, advised a reader to “Go west, young man!” because Greeley saw that was where opportunity and the future were to be found. We feel similarly about the new frontier that is opening up as a result of developmental neuroscience: it is a domain of knowledge that is rich and attainable, and it will become vital territory in the career of psychotherapists. To produce lasting change in developing children, we must understand how young brains (as well as young minds) work. The approach offered in this book attempts to synthesize what is known about developing brains and the therapeutic approaches that have been supported by research. By combining the findings of developmental neuroscience with evidence-based practice, we offer a brain-based therapy for children.
CHAPTER 1

Changing and Staying the Same

No matter where you go, life moves forward like a heavy wheel and it never stops regardless of any circumstance. It just moves forward regardless, and I find that extremely humbling.

—Lisa Kristine, Photographer

Child therapists work in the space between the stable and changeable aspects of personality and character, using the therapeutic relationship to promote a healthy adaptation to living in a complex social world. The discovery that such a relationship could change the mind ignited the psychotherapeutic revolution in psychiatry. It does not seem widely remembered that the discovery was made by pioneers who at the time were immersed in the study of the brain and nervous system. Between 1877 and 1900 (when The Interpretation of Dreams was published), Freud authored more than 100 works on neuroscience. (For an interesting discussion, see Solms & Saling, 1990.) As a neurologist, Freud revised the prevailing view of his scientific contemporaries that the brain did its work piecemeal, with specific parts performing particular tasks in a straightforward way. In a short article on aphasia, for example, Freud rejected the localization hypothesis in favor of the concept of a “speech field” in the brain (1888/1990), a view more in accord with that of modern neuroscience.

Like Freud, William James was also a neurophysiologist. While his work is ultimately less useful to clinicians than Freud’s, James nonetheless laid the basis for much of current cognitive science, and in that sense was a precursor to behaviorism and cognitive behavioral therapy. In his 1890 Principles of Psychology, James discusses some ideas that came to have
enduring importance in psychological studies, including associative learning, chains of operant learning, and fear conditioning. His theory of emotion was based on the idea that feelings arise not from thoughts or fantasies but rather from visceral and muscular responses to outside stimuli. The Principles of Psychology includes detailed diagrams of the brain and a review of Broca and Wernicke’s areas (two areas of the brain that are key to our ability to express and understand language). Regarding the seat of consciousness, James concluded:

For practical purposes, nevertheless, and limiting the meaning of the word consciousness to the personal self of the individual, we can pretty confidently answer the question prefixed to this paragraph by saying that the cortex is the sole organ of consciousness in man. If there be any consciousness pertaining to the lower centres, it is a consciousness of which the self knows nothing. (James, 1890, p. 67)

Subsequent clinically-oriented psychologists followed Aristotle, Descartes, and James in largely disregarding the brain, and followed Freud in focusing on case studies and on developmental cognitive and behavioral norms. Abandoning brain science in favor of pure psychology allowed psychotherapists to employ methods considered “unscientific” by biological scientists. These included the use of insight and empathy as ways of understanding the mind. The separation from neurology allowed therapists to grasp a truth about neuroscience that for many years eluded scientists in laboratory: the brain is exquisitely sensitive to the interpersonal environment of relationships. Particularly in childhood, relationships are as important as food and warmth.

Psychotherapy’s discoveries about human nature and development outstripped what could be demonstrated in the neuroscience labs of the same period. But in pursuing the purely psychological strategy of Freud and James, those of us who have grown up in the psychodynamic and behavioral traditions postponed an important reality check on intuitive hypothesizing and speculation.

The way in which contemporary neuroscience causes us to revise the common psychodynamic understanding of unconscious phenomena exemplifies the value of an integrated neurodevelopmental model. Classical psychoanalytic theorists tended to portray the unconscious as the Puritans portrayed hell—a cauldron of aggressive and libidinal impulses threatening to spill over and destroy both the social order and the individual’s cohesive sense of goodness. Later psychodynamic therapists viewed it in less vivid terms, as the repository for socially and
personally unacceptable impulses. In contemporary neuroscience, if the Freudian unconscious exists at all, it is seen as a small subset of a much larger area of mental life that functions outside of awareness. Much of what the brain does never achieves consciousness, nor would there be a purpose in its doing so. Neuroscientists are careful to use the term “nonconscious” as an adjective, not (as the Freudians tend to do) as a noun. The mind, in the new neuroscience, is a process rather than a thing or a place. Neurodynamic therapists are less impressed with insight than with integrating brain functions and the psychological domains of thought, emotion, and behavior.

Neuroscientific research has demonstrated that nonconscious functioning has a developmental history that is often clinically relevant, one that clinicians should be generally aware of. A brain module that plays a key role in certain types of memories is the hippocampus (or little “seahorse”) located near the center of the brain at the heart of the so-called limbic system. The hippocampus is critical in forming memories about events that can be brought to consciousness. It organizes and coordinates input not only from many other parts of the brain but from the whole nervous system in a way that permits these inputs to be stored as explicit memories. Adults who have the misfortune of losing all or part of this small brain module (such as the famous patient H.M., about whom we wrote in *Brain-Based Therapy with Adults*) stop coding long-term explicit memories, as was the case with H.M. immediately after the surgery that removed his left and right hippocampi.

Hippocampal functioning changes over time, by parallel developmental processes in many other brain modules. The sequence in which the underlying biology of memory emerges is clinically important: the specific loops between the hippocampus and the cortex that allow us to explicitly recall events from the past do not become functional until about age 2. We do not have the capacity to organize explicit memories before that age. No matter how much we analyze the defenses of a child or adult patient, these memories cannot be “uncovered.” Infantile amnesia is not psychogenic, as Freud proposed, but an artifact of this developmental sequence. This fact about the development of the explicit autobiographical memory system has a significant impact on the child’s personality and sense of personal continuity and identity.

Other memory systems come on line earlier in life. The implicit memory system (including procedural and emotional memory), is powerfully influenced by a module located quite close to the hippocampus, called the amygdala (or “almond,” so-named because of its shape). The amygdala, like the hippocampus, is bilateral; that is, it is made up of two relatively small
pieces of real estate, one in each hemisphere of the brain. The amygdala is a powerful mediator of somatic reactions to stress and a potent influence in the laying down of nonconscious emotional memories. These memory systems can be sensed only through the hints and feints of behavior. Thus when we as therapists explicitly interpret a behavior that is linked to (for example) an implicit memory of repeated infantile abandonments in an 8-year-old patient, we are constructing a new narrative with the patient, and not “uncovering” it.

NEURODYNAMICS: SELF-ORGANIZATION AND CHILD DEVELOPMENT

The mind is an example of an “emergent process,” a phenomena found only in complex systems, such as a child’s brain. Emergent processes are the surprising effects produced by the interaction of elements in a complex system, such as the interaction between the hippocampus and the cerebral cortex. Complex systems such as the mind/brain process transform the roles of the component subsystems themselves—very much a case of the whole being greater than the sum of the parts (Arden, 1996; Grigsby & Stevens, 2000).

COMPLEXITY

Complex systems have several important qualities in common, one being that although typically they are made up of many parts, the relationship between the parts is more important than the function of any one component. For air-breathing mammals, for example, the lungs are a vital organ of the circulatory system, but lung functions are affected by larger somatic systems, especially the brain. Conversely, the lungs are much impacted by the vigor of the tiny processes in the cells that make up the lungs themselves. Children’s brains are also made up of many different highly interrelated parts, or modules, which are modified by developmental phases and by experience. When a single cell reproduces itself, creating identical twin offspring, a long process of differentiating begins. One of these cellular offspring will become the great-grandparent of cells that make up the gut; the other the neurons in the visual cortex at the back of the brain. Given that the two offspring are initially identical to the parent cell, what is built-in is the capacity to respond to, among other things, the cell’s location in the environment of the womb and later its location in the fetus.

When a normal baby emerges into the world a scant 9 months or so after the first mitosis, this system of intense gene-environment interaction
continues the work of differentiation. Still in a premature state compared to all other newborn mammals, but with many highly differentiated systems, human babies are especially designed to attach to caregivers. *In this sense, the child is a subsystem in an interactive social system of other individuals and groups.* Like other living systems, the newborn’s brain balances between stability and disequilibrium; and also like other living systems (von Bertalanffy, 1968), it has the capacity to organize itself (Arden, 1996). As we describe in Chapter 2, infants have emerged from the evolutionary process custom-made to attract just the kind of attention they need to survive and prosper. Whatever neurological structure they bring into the world immediately begins interacting with, and is changed by, the environment.

How do complex systems organize and maintain themselves and deal with new inputs into their system? The capacity to maintain a degree of stability in a changing environment is one shared by all complex systems, whether alive or not.

An example of this self-organizing property in a nonliving system is the “behavior” of the planet Saturn and its rings. Through the telescopes of Earth-bound stargazers, Saturn’s rings look like solid flat bands of color attached around the waist to the orb of the planet. Closer observation, however, shows the rings to be made up of billions of rocks hurtling around the planet at tremendous velocity. Moreover, the rings are actually discrete modules in a large, complex system, with empty space separating them.

This pattern is what students of dynamics call an attractor, a pattern of activity or structure the system can assume at minimal expense in energy. The whole system can be said to be self-organizing in the sense that a rock that happens into one of the no-fly zones between the rings will be pulled into an adjoining ring by the force of gravity. A rock that tries to go its own way must tap into some source of energy to stay out of the attractor pattern. All complex systems, including children’s brains, share common elements, and this is one of them: change often requires additional energy. Resistance is not necessarily a willful act of rebellion so much as the tendency of systems (but far more complex) to remain in inertia and conserve energy (Grigsby & Stevens, 2000).

The child’s brain shares some of the dynamic complexity of Saturn’s ring system, including the capacity to organize and maintain itself in certain patterns of activity. Students of dynamics call these patterns “attractors” whether they are the way boulders and bits of debris orbit Saturn or are “traits” we see in a child. But the complexity of a neonate’s brain dwarfs that of the giant planet’s ring system. The fertilized egg and every subsequent cell in the body of the fetus retains all the information in its DNA
that is required to make any of the specialized cells in the body. Every cell seems to be responsive to and changed by environmental factors. Between 10 and 26 weeks, fetuses generate on average 250,000 new neurons per minute. By birth each of these cells will be virtually exactly in the right spot, ready to sprout a precise network of dendrites, or extensions from the neuron used to communicate with colleagues. The dendrites grow in the direction of neurons that will become part of networks required to launch the brain functions that come on line at birth or in the months and years afterward.

How do these cells strike exactly the right equilibrium between stability and the capacity to change? As the internal microelectrical storms within the neuron result in the cell “firing” and discharging a cascade of neurotransmitters in the direction of colleague cells, the recipient of the transmitter reacts. The transmission electrifies or calms down the weather inside the neighboring cell, and mental life begins. There are a staggering number of cells involved in the whole system. Newborn babies have twice as many neurons as their mothers, and the pace at which they start to wire in reaction to outside stimulation is astonishing. Within an hour after birth, the infant starts to imitate the facial expressions of those around him or her (Meltzoff & Moore, 1977), and very soon prefers the configuration of human features to anything else in the visual environment (Bebee & Lachman, 2002). We do not really understand how neurons seem to “know” their proper destinations, nor how they also seem to know which other cells, sometimes far away, they should connect with. What we do understand is that the whole system is exquisitely attuned to sensing the environment; and that the environment immediately begins to play a major role in reorganizing the newborn brain. This is one of the enduring self-organizing properties of the human nervous system.

**Complexity and Environmental Sensitivity**

Helping children requires an appreciation of how susceptible each child is to the relationships surrounding him and some understanding of how he views the world at any particular time in his development. Relationships drive human development, and the child’s relationship with her therapist is just one in a constellation of attachments to adult caregivers and peers. Helping facilitate change in a child’s adaptation to the specifics of his family and the outside world is always balanced with where the child is starting from. In this context, the therapeutic process is a dialogue between the child’s existing ways of interpreting feelings and events
and the therapist’s more developmentally advanced capacity to understand and interpret these phenomena. More than that, child therapy is a bond between two people that produces change in the brains of both participants.

The extent to which children are embedded in an interpersonal environment is illustrated by research on the effects of environments that are either deprived or particularly stimulating. Rene Spitz (1983), a psychiatrist and close associate of Anna Freud, was a pioneer in the area of exploring the interactive role of brain development and relationship-dependent learning in infancy. He originated a method of studying infants and children in relationally impoverished environments, a technique as important in our understanding of the delicate interplay of love and brain tissue in children as the study of the effects of head trauma has been in the evolving model of adult brain functioning. The principle here is that to understand how things usually work, look at what happens when they go disastrously wrong. Spitz studied medically hospitalized infants and formulated the concepts of hospitalism and anaclitic depression. Left alone for long periods of time, the infants in Spitz’s studies typically actively protested and then, if no one responded, withdrew and became passive. Infantile withdrawal could become complete and lead to an ultimately fatal shutting down. Babies, Spitz proposed, can die from not being touched, spoken to, looked in the eye, smiled at, and bounced.

Romanian orphanages have been an important field site for researchers interested in infant maternal and social deprivation. After the overthrow of the Ceausescu government in 1989, more than 150,000 children were found languishing in orphanages. Many were malnourished, neglected, and dying of infectious diseases in disproportionate numbers. In these settings, one person typically cared for approximately 30 children. Babies were fed and kept clean but their psychological needs ignored. Many had resorted to methods of self-stimulation, such as head banging, rocking incessantly, and hand flapping. A major cause of their multiple developmental delays was the lack of consistent human contact during critical periods (Kuhn & Schanberg, 1998).

Infants of less than a year who had been placed in Romanian orphanages for more than 8 months were shown to have higher cortisol blood levels (an indicator of significant stress) than orphans adopted within the first 4 months of their lives—and cortisol levels continued to increase for those left in the institutions for more than 8 months (Gunmar, 2001). Cortisol is an important part of the brain’s arousal system, which works well over relatively short-term periods. Long-term stress dysregulates the system.
by negatively affecting the functioning of the hippocampus (and even its size) and by throwing the amygdala into overdrive.

British child psychiatrist and neuroscientist Sir Michael Rutter compared 156 Romanian orphans who were adopted by age 3.5 to 50 non-deprived children who were adopted before 6 months of age (Rutter et al., 2001). All the children were followed longitudinally and were examined for a variety of behavioral problems including attachment and emotional problems, attention deficit hyperactivity disorder (ADHD), autism, cognitive impairment, peer relationship problems, and conduct problems. The Romanian children were more likely to exhibit behavior problems in four of the seven domains: attachment problems, ADHD, autistic-like problems, and cognitive impairment. These difficulties were more likely to occur among children who left Romania after their second birthday. Those children adopted prior to 6 months of age resembled a sample of nondeprived children adopted in the United Kingdom. The risk of developing behavioral problems increased linearly if adopted after 6 months of age from a Romanian orphanage and the risk was greatest for children adopted after age 2. Interestingly, even in the sample adopted after age 2, 20% to 25% of the adopted children did not develop behavior problems by age 6.

In Canada, Fisher and colleagues documented the breadth of some of the results of trauma in Romanian children adopted by parents in British Columbia (Fisher, Ames, Chisholm, & Savoie, 1995). They found that children who had spent at least 8 months in a Romanian orphanage had significant developmental problems; those who spent under 4 months in orphanages did not. Romanian orphans adopted by American families have shown many symptoms of early social deprivation. These children often appear stoic, uninterested in play, tend to hoard food, and rarely cry or express pain. Imaging studies show abnormalities in the brains of orphans consistent with these behavioral deficits. Areas vital for conducting relationships and self-regulation, such as the orbital frontal cortex (OFC), are underactivated relative to those of normal children (Chugani et al., 2001).

Maternal deprivation apparently also causes significant neurochemical abnormalities. Research on adult animals separated at birth from their mothers has revealed persistent irregularities in the production and normal functioning of neurotransmitters (the chemicals that communicate across the synapses that separate neurons). Dopamine, a transmitter important in the experience of pleasure and reward, is one of the neurochemicals affected by attachment experiences. Early deprivation alters the expression of the genes that regulate dopamine manufacture and the role dopamine
plays in mediating stress. The negative effects of early maternal separation identified in other animal studies include: the expression of serotonin receptors in RNA, the expression of benzodiazepine receptors, and the infant’s sensitivity to morphine and to glucocorticoid receptors related to the stress response. (See Wexler, 2006, for a review.) The work of developmentalists such as Spitz and of contemporary neuroscientists on the devastating effects of early interpersonal deprivation have changed social policy around the world. As studies have accumulated confirming that stable relationships are a basic nutrient of development, the research has helped transform protocols in orphanages, pediatric wards, and daycare centers. Institutions with the resources to do so have moved to provide higher levels of interaction and consistent caretakers for infants. Unfortunately, where the resources to make these changes are lacking, the toll on infants continues unabated.

**Neuroplasticity and Neurogenesis**

Studies of children in so-called enriched environments take a different slant on the issue of the impact of environmental factors on brain development but produce results consistent with research on extreme deprivation. Animal subjects are often used as stand-ins for humans in these studies because these studies use post-intervention autopsies; and rats are particularly popular because they breed readily in captivity and mature relatively quickly. Over 40 years of exposing rats to enriched environments has shown a wide variety of structural changes in their brains. These include overall increases in brain weight and density, more growth in the dendrites, increased density of dendritic spines (which facilitates interneuronal communication), more synapses per neuron (ditto), more multiple synaptic buttons (ditto again), and more granular cells in the dentate gyrus of the hippocampus. (See Cicchetti & Curtis, 2006, for a review.)

The last finding—that the brain actually makes new neurons in response to environmental stimulation—is an important one. Researchers from the Salk Institute for Biological Studies in San Diego put adult mice in cages equipped with tunnels, wheels, and other environmental attractions. They found that the mice placed in the enriched cages developed 15% more neural cells than mice put in standard cages. As expected, they performed better on various cognitive and memory tests and were found to have enlarged hippocampi (Kemperman et al., 1998). The so-called neuronal proliferation appeared to involve the precursor to neurons called neuroblasts, which develop out of stem cells. Normally, stem cells and neuroblasts develop throughout adulthood but do not generally survive to
become new neurons. The Salk group, however, demonstrated that cognitive stimulation in enriched environments increases the neuroblasts’ odds of becoming actual neurons.

These findings contradicted a belief long held by most neuroscientists that we are born with all the neurons we will ever have. Studies such as the Salk Institute’s have changed the field’s collective mind. The discovery that new neurons are created in specific areas of the brain, such as the dentate gyrus of the hippocampus, has deepened recognition of the brain’s responsiveness to new learning. Taking psychotherapy as an example of an enriched interpersonal environment, it is probable that neurogenesis comes into play in our offices as well as in the laboratory. It has been estimated that as much as 85% of the dentate gyrus neurons are generated postnatally. These granule cells are excitatory and use glutamate as their primary neurotransmitter. Kemperman and colleagues (1998) also found new neurons in the dentate gyrus of mice placed in enriched environments. Gould and colleagues (1999) have demonstrated the same phenomenon in the brains of adult monkeys.

With some intuitive sense of the power of the environment to affect biological changes in the brain, the educational system has tried to harness enrichment as an intervention. Head Start is a sterling example of such a program. Imaging or other direct evidence of structural change in the brains of Head Start children is not available, but changes in the behavior of children who participate provides strong clues as to what is going on in their heads. An increase in average IQ scores and positive impacts on school and social competence are among the program’s benefits (Lazar, Darlington, Murray, Royce, & Snipper, 1982). Another program, the Abecedarian Project, has also shown positive effects on the cognitive development of high-risk young children (Gottlieb & Blair, 2004; Ramey et al., 2000). Children who attended the program achieved a 5-point IQ advantage over controls. The enrollees showed a 50% reduction in failing grades in elementary school compared to controls, and between the ages of 12 and 15, they scored well on a variety of achievement tests. Those children who were at the greatest risk—for example, those with mothers who had IQs lower than 70—benefited most from participation in the program.

**GENETICS AND ENVIRONMENTAL EFFECTS**

Studies of adoption generally (but not always) support the importance of the environmental contributions to individual development. In one study, children whose biological families had a history of violence were adopted
into families with no such history. Only 13% of the adopted cohort expressed antisocial traits as they grew up, in contrast to 45% of children from nonviolent biological origins adopted into families with aggressive histories (Cadoret, 1995).

Twin studies produce perhaps the most compelling examples of the relative importance of environmental versus genetic influences on the development of particular psychological traits. In one such study, identical twins described as “secure” in their initial assessment were placed in settings with an anxious adoptive parent. Outcomes suggested that anxiety is catching, insofar as the twins typically developed the anxious trait of the adoptive parent (Bokhorst et al., 2003).

A child’s environment may include a mixture of risk and protective factors. For example, a longitudinal study conducted on the Hawaiian island of Kauai followed 700 children born in 1955. Half of the children lived in poverty and half in relative affluence. One-third of the study population developed behavioral problems. Those particularly susceptible were exposed to risk factors such as prenatal illness, chronic poverty, parental psychopathology, and family instability. But interestingly, some 70 children (10% of the population) who had been exposed to multiple risk factors nevertheless grew into caring and competent adults. The protective factors for these children were identified as including the following:

- The mother’s caregiving competence
- The child’s own social maturity, autonomy, sense of self-efficacy, and scholastic competence
- Emotional support from the extended family and friends

The interplay between the expression of genetic endowment and the stimulating effects of the environment come together in a complex, mutually reinforcing pattern we called nurtured nature in the adult volume of this series. We use the term to capture the reciprocal impacts of interpersonal environment and the brain of a developing person, regardless of their age. Overall, the relationship between risk and resilience within the nurtured nature paradigm draws on many factors. In Rutter’s study of severely deprived Romanian orphans adopted by British families, 20% to 25% of the children were able to rebound and assume a normal developmental course within a loving family. The factors involved in the success stories are a blend of the personal and the systemic, just as they were in the Hawaiian children.

In terms of the mixture of protective and risk factors that characterize the genetics and environments of the children we see, the therapist’s job is
complex. Development is not based on nature or nurture alone. Every child comes into the world with a unique genetic history. Maximizing their potential for resilience in the face of risk is the task of brain-based therapy. We seek to recruit and foster the protective factors by positively impacting the parenting children get and by offering a relatively brief exposure to a cognitively and emotionally enriched environment. In Chapter 2 we examine attachment as an aspect of “nurture” and the child’s temperament as a force of “nature.”

DEVELOPING BRAIN

What makes us so susceptible to environmental influence? How is it possible to change in the course of a therapeutic relationship? The answer to these questions lies in the anatomical structure, dynamic functioning, and developmental history of the brain. Three types of brain development have been identified: gene driven, experience expectant, and experience dependent (Black, Jones, Nelson, & Greenough, 1998; Greenough, Black, & Wallace, 1987).

GENE-DRIVEN DEVELOPMENT

Gene-driven brain development is relatively insensitive to experience. Much of this development occurs prenatally (e.g., in the migration of neurons to their appropriate anatomical positions). Prenatally, the brain begins as a hollow cylinder, called a neural tube. Neurons are generalized along the inner walls of the neural tube and migrate to their proper locations (Kolb, 1989). The most prolific period of embryonic neuron formation (neurogenesis), as we’ve noted, is between 10 and 26 weeks. The brain over-produces neurons and will sacrifice about half of them in a process known as apoptosis, or neural pruning. Apoptosis (a phenomena of programmed cell death) is characterized by cell shrinkage and fragmentation of the nucleus, followed by the removal of the dead cell by phagocytes.

Cell migration essentially involves neurons positioning themselves in areas of the brain with semispecialized functions. For example, in the cortex, neurons migrate to six cortical layers, each having distinct functions. The neurons within each layer project to specific targets or receive afferents from specific sources. For example, layer 2 neurons participate in short inter-cortical connections. Layer 3 neurons participate in longer range cortico-cortical connections as well as interhemispheric communication across the corpus callosum, the central bridge linking the two hemispheres of the brain. Layer 4 targets nerve fibers coming from the thalamus (the
central switchboard of the brain). Layer 5 is the origin of projections from the cortex to subcortical structures, such as the amygdala and cerebellum (at the back of the brain, near the brain stem). Layer 6 neurons project to the thalamus (in contrast to layer 4). About the connectivity of the neurons in layer 1, as yet we know very little.

Cell migration is complete by 7 months gestational age (Huttenlocher, 1990). However, genetic defects or exposure to teratogens may produce disruptions in the migration of neurons to their expected destination (Gressens, 2000). These events can occur as a result of the mother’s exposure to neurotoxins, including alcohol and drugs.

After neurons have migrated to their home territory in the nervous system, cell elaboration marks the next phase in brain development. In this phase, axons and dendrites form synapses with other cells. Just as the developing brain produces more neurons than it will need, it also produces more synapses than will survive. The brain of an infant or toddler has far more synapses than an adult’s brain. At peak times, as many as 100,000 synaptic connections will be pruned (Kolb, 1995). Neurons and synapses that survive are the winners in a process called neural Darwinism, with “fitness” determined by the frequency of contact from other neurons (Edelman, 1993). Those that are relatively isolated die off.

**Hemispheric Specialization**

A general overview of brain processes and modules appears in the appendix of this book; but for the present, we must note one of the best-known anatomical features: the brain, like the face, is bilateral. The left side and right sides look slightly different if you examine them closely; and they are somewhat specialized in function (although just how much, and in whom, is a matter of lively debate, with Nobel Prizes awarded to the winners).

There is evidence that hemispheric specialization begins prenatally and that, at birth and for some time afterward, the right hemisphere is more dominant in infant functioning. Areas of specialization that are generally agreed on in the literature are shown in Table 1.1. A caveat is that females typically demonstrate less hemispheric specialization than do males, and males may be overrepresented in the specialization data.

In general, the right hemisphere is linked to novelty and the left hemisphere to routine (Goldberg, 2001). The way in which the brain processes music is an example. An overgeneralized and now-discredited belief is that music appreciation is a right-hemisphere task. It now appears that musically naive people process music with their right hemisphere because of the novelty. Trained musicians, however, process music mostly
Consistent with this finding, Alex Martin and colleagues from the National Institute of Mental Health used positron emission tomography (PET) scans to measure blood flow patterns and demonstrated that as individuals learn tasks, novel information initially is processed by their right hemisphere. When the information becomes familiar and routine, it is lateralized to the left hemisphere (Martin, Wiggs, & Weisberg, 1997). This appears to be the case with both verbal and nonverbal information. Individuals demonstrate fascinating and heartening capacities to deal with adverse brain events in regard to these standard hemispheric arrangements; for example, a child who suffers right-hemisphere damage is likely to recover some capacity to process novel stimuli. The earlier in life the damage is sustained, the more likely the person will recover significant functioning.

**Postnatal Development:** Also a part of gene-driven development is the pace at which the normal brain in an average environment develops. At birth, babies’ brains have achieved only 25% of their adult weight—but their bodies, by comparison, weigh just 5% (on average) of what they will weigh as an adult. At 6 years of age, the child’s brain has attained 90% of its adult weight (Kolb & Wishaw, 2003). This accelerated brain growth in childhood is one of the developmental landmarks that differentiate us from other species. The fastest developing part of the child’s brain is the cerebral cortex, including the prefrontal cortex (PFC), at the forefront of the frontal lobes. It facilitates cognitive, emotional, and social functioning at a uniquely human level. But this high-powered “wetware” inside the child’s skull requires high maintenance. Honed by evolution to nurture and protect this most unique evolutionary advantage of our species, the human