Neurobehavioral Disorders of Childhood

An Evolutionary Perspective

ROBERT MELILLO
and
GERRY LEISMAN

Neurobehavioral Disorders of Childhood

An Evolutionary Perspective

Robert Melillo • Gerry Leisman

Neurobehavioral Disorders of Childhood

An Evolutionary Perspective

Springer

Robert Melillo
Department of Clinical Neurology
Carrick Institute for Graduate Studies
203-8941 Lake Drive
Cape Canaveral, FL 32920
USA

Gerry Leisman
Department of Psychology
College of Staten Island
City University of New York
2800 Victory Blvd.
Staten Island, NY 10314
USA
drgersh@yahoo.com

ISBN 978-1-4419-1232-9 e-ISBN 978-1-4419-1231-2
DOI 10.1007/978-1-4419-1231-2
Springer Dordrecht Heidelberg London New York

Library of Congress Control Number: 2009935459

To
My wife, Carolyn, and my children, Robby, Ellie, and Ty.
I love all of you. You are my life's inspiration.
To my parents, Joseph and Catherine, my brother, Domenic,
my sister, Susan, and their children for all of your love and support.
To Ted Carrick for your friendship and professional inspiration.
To Janet Groschel for your friendship and support; this book
would not have been possible without all of your help.
Thank you.

To my wife and best friend
Yael
And all of our children
Yael, Amit, Akiba, Michal, and Daniel

Foreword

Attention deficit/hyperactivity disorder (ADHD) affects 3–8 percent of children and is associated with social, cognitive, and academic impairments. The DSM-IV estimates the prevalence in children closer to 10 percent with a predominantly hyperactive impulsive type or a predominantly inattentive type. With prevalence estimates of ADHD ranging from 1.9 percent to 17.8 percent and the persistence of the disorder into adulthood in 10–60 percent of the child onset cases, the consequences of this disorder are far reaching.

Over the last decade, there has been a dramatic increase in the number of ADHD-related visits to health care providers with an associated increase in pharmaceutical intervention in children. Conservative estimates of greater than 10 million prescriptions for methylphenidate in the United States alone support the increased incidence or recognition of a serious developmental problem. The personal, familial, and societal consequences associated with inappropriate over activity, distractibility, inattention, and impulsive behavior in children and adults are alarming.

Educators have identified problems in test-taking and difficulty completing homework that reflect the poor organizational skills which carries over into adulthood. Delinquent and antisocial behaviors are commonly associated in the male ADHD sufferer. Females make up approximately 10–25 percent of cases with a male to female ratio ranging from 4 : 1 for the predominantly hyperactive impulsive type to 2 : 1 for the predominantly inattentive type.

The DSM-IV criteria for ADHD require that a minimum of six symptoms of inattention or a minimum of six symptoms of hyperactivity–impulsivity occurances are noted. The symptoms must be present before the age of 7 years and must have persisted for a minimum of 6 months before a diagnosis might be made. The diagnosis of ADHD is largely subject to an individual fitting DSM-IV criteria leaving the clinical examination to act as a mechanism that might identify other medical or neurological disorders.

Physicians, educators, therapists, parents, and sufferers are searching for answers to their many questions regarding ADHD. In their textbook *Neurobehavioral Disorders of Childhood: An Evolutionary Perspective*, Drs Melillo and Leisman present such answers. The book is uniquely different as it is written by a clinician and a neuroscientist who have embraced a concern for society with an expression of humanism.

Rob Melillo and Gerry Leisman have specialized in the diagnosis, treatment, and science of neurological disorders for over 30 years. Their extensive clinical knowledge of neurology is evident and facilitates an understanding of the disorder of autistic spectrum disorders. Refreshingly, their work is not limited to the neurological but encompasses a unique historical or developmental approach to the subject that promotes an awareness of autistic spectrum disorders in a manner not before presented.

This text will promote change and better understanding of a complex dilemma. It will be well used by health care providers, educators, parents, and all of us concerned with the optimally developing child. I was honored to have been asked to write a foreword to this work, but blessed to have been fortunate enough to read it.

Frederick Carrick
Professor Emeritus of Neurology, Parker College
Distinguished Post Graduate Professor of Clinical Neurology, Logan College

Contents

1

Introduction

Childhood neurobehavioral disorders share many features in common. While often referred to as *Learning Disabilities*, the implication of such a term would indicate that the primary manifestation of these childrens' condition affects classroom behavior exclusively and that the rest of their development proceeds smoothly and without incident.

Attention deficit disorder (ADD), *attention deficit hyperactive disorder* (ADHD), *pervasive developmental disorder* (PDD), *obsessive–compulsive disorder* (OCD), *Asperger's* syndrome, and *Autism* to name but a few, may be viewed as points on a spectrum of developmental disabilities in which those points share features in common and possibly etiology as well, varying only in severity and in the primary anatomical region of dysfunctional activity.

As this text focuses on alterations in the normal development of the child, it would be natural and useful to develop a working theory based on what we know of the development and evolution of the human species and its brain.

In outlining our theory of developmental disabilities in evolutionary terms, we will offer evidence to support the following notions:

1. *Bipedalism was the major reason for human neocortical evolution*. We propose that bipedal locomotion is phylogenetically the most sophisticated and complex movement. It is unique to humans and was responsible for the development of the large human brain. This occurred, we postulate, because of the bipedal posture's unique ability to harness gravitational forces through the now upright postural motor system. Bipedalism has been utilized as a power source to maintain a genetic mutation, having created larger pools of neurons. The same evolutionary process has allowed us to develop the binding of the motor system into a synchronous, rhythmic, purposeful movement, which expanded to eventually allow for cognitive binding or consciousness.

Postural muscles, we claim, were the main conduit for this motor and cognitive binding to evolve and continue to exist. Deviations from normal postural development or from normal levels of postural activity can disrupt or delay *cerebellar* and cortical maturation and may disrupt the underlying oscillatory timing mechanisms on which both motor and cognitive binding is based.

2. *Cognition evolved secondary and parallell to evolution of motricity*. We will explore the relationship between cognitive and motor functions from an evolutionary perspective.

R. Melillo and G. Leisman, *Neurobehavioral Disorders of Childhood: An Evolutionary Perspective*,
DOI 10.1007/978-1-4419-1231-2_1,

We will demonstrate that cognitive and motor functions are actually part of the same function, even though they have been historically viewed as separate. They both evolved in parallel as a product of the evolution of sophisticated complex movement. The same underlying mechanisms that evolved to enable more complex coordinated movements were adapted and utilized to effect more sophisticated cognitive processes.

3. *There exists an overlap of cognitive and motor symptoms*. Another major theme to be explored includes the articulation of *cerebellum*, *basal ganglia*, and *frontal lobes*, which are areas of the brain recognized to control motor and nonmotor intentional and executive function. Most developmental disabilities have as their most common symptom, motor incoordination or clumsiness, especially of posture and gait. Impulse control, either inhibited or facilitated, and judgment disorders can all be attributed to dysfunction of this network and its control of motor and nonmotor behavior. This spectrum of disorders all involve disruption primarily of what is known as executive functions which are functions attributed to the *frontal lobe*.

4. *Lack of thalamo—cortical stimulation not overstimulation is a fundamental problem of developmental disabilities*. We postulate that under stimulation of the *cerebellum* and *thalamus* produces a disruption of normal thalamocortical oscillations disrupting the ability to bind motor and cognitive functions in space and time. This temporal incoherence particularly affects the higher *frontal lobe* functions or executive functions and its reciprocal connections to the *basal ganglia*. This results in disruption of both executive and motor functions since these areas (the *frontal lobe*, *basal ganglia*, and *cerebellum*) are primarily responsible for both. Various studies show decreased activity and size of the *cerebellum*, *basal ganglia*, and *frontal lobe*, which is consistent with functional losses seen. Stimulant medication especially medications that increase *dopamine*, in children with developmental disabilities, have been shown to improve symptoms by increasing stimulation to those areas. *Dopamine* is the most common neurotransmitter in this motor system network and its dysfunction has been implicated in many neurobehavioral disorders in adults.

5. *A primary problem is dysfunction of hemisphericity*. We will explain why despite these conditions having a possible common neurological basis, children still present different symptoms. The explanation is that a primary problem relates to the failure to achieve equal activity and resonance in both right and left cerebral hemispheres. There exists an asymmetric distribution of almost all human functions within the cerebral cortex including cognitive, motor, sensory, neurohormonal, immune, autonomic, and endocrine. Failure to develop and achieve temporal coherence between the two hemispheres results in a form of functional independence of each hemisphere, resulting in adaptive functioning of the brain and its control properties. This may sometimes result in extremely high degrees of functioning in specific tasks. An example is the *savant* syndrome, but the same process is seen throughout all disorders in the spectrum and may even be a basis for individual differences in cognitive style. We will discuss the ramifications of viewing many of the cognitive and motor effects of developmental disabilities as based on a functional disconnection syndrome. Additionally, it will be noted that in these children, global functions are not affected, but many specific functions are decreased while others are enhanced, demonstrating region specific brain effects.

6. *Most conditions in this spectrum of disorders are the result of a right hemisphericity*. Most developmental disability syndromes can be clearly related to dysfunction or delay in development of the right hemisphere. The right hemisphere is understimulated resulting in slower temporal processing within that hemisphere, especially in the *frontal lobe*. This slower temporal processing results, in turn, in decreased effectiveness of the right hemisphere's normal executive functions. This decrease in activity has been shown with modern functional imaging of the brain, which has noted a decreased activity in the

right frontal cortex with an asymmetric distribution of activity in the *basal ganglia* and *cerebellum*. This right hemisphericity may also explain why males are affected more than females. Almost all of the specific disorders described earlier are found with significantly greater frequency in males. The frequency ranges from approximately 6 to 1 in *ADD* to 50 to 1 in high functioning *autistic* individuals. Male brains are more asymmetrical than female brains. Male brains are more susceptible to prenatal and postnatal influences; these influences, which primarily consist of maternal prenatal levels of estrogen, create this greater right cortical development than left characteristic of male brains. It has been further noted that *dopamine* decreases have a greater negative effect on right frontal cortex function than left due to the asymmetrical distribution of *dopamine* receptors in the brain.

7. *Environment is a fundamental problem.* Although genetic predispositions are likely to be present, the main factors in causation of developmental disabilities are hypothesized to be environmental, especially in the more severely afflicted. The dramatic rise in the diagnosis of these problems is not consistent with a purely genetic cause. We intend to demonstrate that current socially acceptable childhood behaviors, primarily those which are sedentary, such as a high proportion of time spent by the child watching television or playing video games, is a primary factor for the dramatic increase in neurobehavioral problems of childhood. The human brain is extremely plastic allowing us to adapt to the environment in which we develop. The long postnatal development in humans is primarily responsible for this flexibility. Although this has some obvious advantages from a evolutionary perspective it also makes the human brain more susceptible to negative environmental influences or lack of appropriate environmental stimuli. The window of time for the greatest development is between conception and the age of 6. Motor activities facilitate this brain development, particularly in males. A dramatic decrease in early motor activity will affect development of gross motor behavior, which is more specific to right hemisphere development. Sedentary behavior is pervasive amongst children and has been witnessed by dramatic increases in their obesity rates. These increased rates are comorbid with the rates and time frame of the increase in learning disabilities and neurobehavioral disorders. The primary social influences negatively affecting cognitive and motor functions in childhood consist of the increased use of television, VCR, computers, working parents, and parental fears for their children. Other environmental factors such as poor nutrition, increased caloric intake, environmental toxins, and early sensory deprivation are other important factors but are not as significant as sedentary behavior.

8. *All of these conditions are variations of the same problem.* We conclude that most developmental disabilities are of similar etiology and are variations of the same underlying problem. A high rate of comorbidity exists for all of these conditions. The *frontal lobes*, *cerebellum*, *basal ganglia*, and *thalamus* have been implicated in all of these conditions. This has been documented on static imaging such as CT scans and MRI, as well as functional imaging such as PET scans and fMRI. In addition, *dopaminergic* system involvement is highly related to each of these conditions in a way similar to that found in adult neurobehavioral disorders such as schizophrenia.

9. *These problems are correctable.* An additional theme propounded in the text concerns intervention strategies to remediate these conditions. As brain organization is plastic, many aspects of neurobehavioral disorders do not have to result in permanent impairment. Appropriate forms of environmental stimulation and behavioral modifications can significantly improve or completely correct the underlying problem. Since motor and cognitive dysfunction often coexist, improving the function of one effects changes in the other. In children, we will demonstrate that the main focus of treatment should be on improving motor performance combined with some cognitive training and behavior modification as necessary. We will demonstrate that motor and cognitive early intervention strategies will effect objective change in an electrical

asynchrony of the two cerebral hemispheres that is associated with positive change in both the cognitive and motor symptoms.

10. *Hemisphere specific treatment is the key to success*. Besides increasing motor performance, timing, endurance, and posture, we will finally address the need for hemisphere specific treatment modalities. Motor activity, sensory stimulation, and cognitive functions directed toward the under-functioning hemisphere is the most important consideration in treatment. Achieving temporal coherence or a balance of activity between the two hemispheres is critical for allowing cognitive and bilateral motor binding to occur, which would reduce hemispheric neglect. As the hemispheres achieve a normal coherence and synchronization, motor and cognitive performance will improve.

We consider this book the beginning and not the end of our work. We present this information so that others may reproduce our results and hopefully improve on them over time. We have used widely-accepted assessment tools whenever possible to help confirm and perfect our diagnosis and to help document the results. Hopefully, we may combine our results with others who will use our program, and we will be able to publish a vast body of information in the coming years. Our children and our society's future may depend on it.

Numerous investigators have reported that the incidence of *autism* spectrum disorders and neurobehavioral developmental disabilities are on the rise (Case-Smith and Miller, 1999; Fombonne et al., 1999; Chakrabarti and Fombonne, 2001). It also has been reported that today's children, in general, seem to have shorter attention span (Chakrabarti and Fombonne, 2001; Keren et al., 2001), more impulsive behavior (Chakrabarti and Fombonne, 2001), and decreasing scores in reading and language skills (Chakrabarti and Fombonne, 2001) than they had as recently as 10 years ago. It appears that these problems are becoming epidemic.

We have also been noting, both clinically and as reported in the literature, an increasing number of adult patients being diagnosed with *ADD/ADHD*, often following physical trauma, such as an automobile accident (Arcia and Gualtieri, 1994). There exists a similarity in the neurological symptoms between adult patients and children diagnosed as *ADD/ADHD*.

*Autistic spectrum disorder*s including *ADD*, *ADHD*, and *autism* itself as well as other learning disabilities are growing at a staggering rate in the United States. In January, 2001, it was reported (Newsday, 2001) that 1 in 10 U.S. children have some sort of mental health problem, but fewer than 1 in 5 of them are being treated. This claim was made by the then Surgeon General of the United States, David Satcher, and reported in the same article. Among the conditions that are reportedly undertreated, include major depression, considered one of the most common, *ADHD*, and *OCD*. Satcher stated, "Short of those diagnosable problems, are problems that children have in their development and functioning very early." Satcher proposed a complete overhaul of how mental health in children is handled from training teachers and doctors, to better recognizing and understanding these disorders, to doing more research and translating that research into effective treatment programs. Satcher is also quoted as noting, "In any given year it is estimated that fewer than one in five of the children suffering from mental illness receive needed treatment."

In an article in *U.S. News and World Report* (2000), it was stated that 1 in every 6 children in America suffer from problems such as *autism*, aggression, dyslexia, and ADHD. In California, reported cases of *autism* rose 210 percent from 3,864 to 100,995 between 1987 and 1998. In New York, the number of children purportedly with learning disabilities jumped 55 percent from 132,000 to 204,000 between 1983 and 1996. "In the past decade, there has been a significant surge in the number of children diagnosed with *autism* throughout California," states the article. In August 1993 the article continues,

> there were 4,911 cases of so-called level-one *autism* logged in the state's Department of Developmental Services client-management system. This figure does not include children

with *Asperger's* syndrome, but only those who have received a diagnosis of classic *autism*. In the mid-'90s, the caseload started spiraling up. In 1999, the number of clients was more than double what it had been six years earlier. Then the curve started spiking. July 2001, there were 15,441 clients in the DDS database. Now there are more than seven new cases of level-one *autism*—85 percent of them children—entering the system every day.

California is not alone. Rates of both classic *autism* and *Asperger's* syndrome are reportedly rising all over the world, which is certainly a cause for alarm and for the urgent mobilization of research. *Autism* was once considered a rare disorder, occurring in 1 out of every 10,000 births (Fombonne, 2003). Now it is reportedly more common—perhaps 20 times more (Chakrabarti and Fombonne, 2001). However, according to local authorities, the picture in California is particularly bleak in Santa Clara County. Here in Silicon Valley, family support services provided by the DDS are brokered by the San Andreas Regional Center, one of 21 such centers in the state.

The total number of children affected at this point, we estimate to be approximately 15 million in the United States alone. No comprehensive treatment methodology exists at present that can effectively ameliorate the broad range of symptoms characteristic of children of *autistic* and neurobehavioral disorders. Drug treatment is not a panacea neither is educational or psychological remediation approaches. Some parents do not want to use medication because they are rightly afraid of possible long-term side effects. For others; the medication does not work very well or at all. While the vast majority of parents feel that psychological therapy is useful, many report that behavioral interventions did not help their children as much as they had hoped. They all feel there should be an alternative.

Most parents of children with developmental neurobehavioral disorders do not have a good understanding of the nature of the etiology of their children's dysfunction. They do not understand what is "wrong" with their children and often blame themselves, feel inadequate, and think of themselves as "bad" parents.

Subjective reports from experienced teachers have consistently yielded opinions that while the *ADD/ADHD* problem might be over diagnosed, there exists a growing problem among significant numbers of children in their classrooms. They have indicated that today's children are different now than children in their classes 20 or 30 years ago. The teachers claim to see a steady decline in the quality of the children's work over the last three decades and this trend seems to have been accelerating within the past 10 years. They find it much more difficult to teach because in today's classroom the children have a harder time paying attention or following instructions. The percentage of children with severe behavioral and language problems is reportedly increasing (U.S. Department of Health and Human Services [USDHHS], 1997). Teachers complain that children do not read as much as earlier generations and their comprehension, when they did read, had decreased significantly. The most frequent and consistent report of the many teachers that have been interviewed is that it is harder to get children today to sit still.

The teachers report that at lunchtime they see children line up in the hallway outside the nurse's office for their medication. "Years ago," one of the veteran teachers said, "... maybe you had one or two children who were hyperactive or with attention problems per class. Now in many instances, it is almost half the children who have problems." They all noted that many of their colleagues were opting for early retirement because they could not take it any longer and felt ineffectual in their careers. They also believe that the problem is getting worse and they are powerless to change it.

When asked if they knew the basis of these subjectively noted changes in school behavior the teachers, like many parents report that they do not really understand the nature of the physiological problems. Teachers appear to be

consistently in agreement with each other. One teacher's response characteristic of so many others is,

> I don't know how it works, but I feel children don't use their muscles as much as they used to. At lunchtime, children do not play on the playground as they used to. They do not run around, they just sit or stand there. They seem less physically active. If you drive around any neighborhood, you do not see children outside. You used to see children out on their bikes or roller skates, climbing trees or playing ball. You don't see that any more. It's not that there are fewer children, in many cases there are more. They are inside watching TV, playing Nintendo or computer games.

She continued, "I don't know exactly what the relationship is or how it works, but I believe that there is definitely some connection."

Another common response from teachers questioned was that teachers reported a conjectural "cause and effect" relationship between increased developmental problems and an increased number of children coming from families where both parents work. They felt that increasing numbers of children from these families have less parental stimulation and fewer meaningful interpersonal relationships. Due to time constraints, parents do not talk to their children as much as they did 10 years ago, or read and spend time just being together. Because of this, the baby-sitter is often the television, video games or the computer, intrinsically solitary activities, so even talking with other people is greatly decreased. Parents attempt to compensate for less time with their children by providing more stimulating activities, or "quality" time between parent and child—just being together and talking and relating with one another.

Healey (1990) in her book "*Endangered Minds*," quotes many interviews with teachers and some interesting studies with startling statistics. As an educator and administrator with 30 years experience, she comments that modern children seem to have "changing brains." Healey notes that youngsters today seem different than those she used to teach, even though the average IQ score has remained fairly stable. She became convinced that the changes are due to the way children are now absorbing and processing information.

Healey writes, "children were likable, fun to be with, intuitive, and often amazingly self aware." Today, in her estimation, they seem harder to teach, less attuned to verbal material both spoken and written. She discovered, "many admitted they didn't read very much, sometimes even the required homework." They struggle with or avoid writing assignments while teachers anguish over the results. One of the teachers she interviewed stated, "I feel like children have one foot out the door with whatever they are doing, they are incredibly easily distracted. I think there may have been a shift in the last five years." Healey (1990) developed a questionnaire requesting anecdotal information of cognitive changes observed in students. She handed it out at national meetings and conferences to experienced teachers working in schools where demographics had remained relatively stable. Approximately 300 teachers responded and there was unanimity in their response. The consensus was that attention spans had become perceptibly shorter and reading, writing, and oral language skills seemed to be declining, even in neighborhoods that were more affluent. Additionally, Healy indicated that no matter how "bright," students are less able to "bend their minds" around difficult problems in math, science, and other subjects as they had been able to previously.

Statistics comparing math and science performance of students from Asia, Europe, and the United States, show that students in the United States are at the "rock bottom," particularly in understanding complex interpretations of data (Healy, 1990). Healey goes on to quote a cover story in Fortune magazine indicating, "... in a high tech age where nation's increasingly compete on brain power, American schools are producing an army of illiterates."

The scholastic aptitude test (SAT) taken by students who intend to apply for college in the United States has shown drastically declining scores (Choy, 2002), particularly in the areas of higher level verbal and reasoning skills. Starting in 1965, the average SAT verbal and

math scores have declined steadily until the mid-1980s, where they leveled off and then experienced a slight rise. Subsequent math scores have remained stable, but verbal scores have begun another gradual decline. Overall, verbal declines have been considerably greater, 47 points by 1988 as opposed to 22 for math (Choy, 2002). In the past, it was shown that children from less priviledged educational backgrounds had poor scores on standardized tests. Recently, scores of minority populations are the only ones showing consistent improvement, with African American students in particular making the most impressive gains (Choy, 2002). This steady decline in standardized testing scores has occurred in spite of the proliferation of commercial courses that claim to successfully prepare students for standardized tests like the SATs, and it happened especially in the privileged groups, whose double income parents can afford the additional expense. Educators agree that for all students, increased television watching and decreased reading negatively influence verbal and attentional performance of children (Kagan, 1971; White, 1975; Woody-Ramsey and Miller, 1988; Ruff and Lawson, 1990). The National Assessment of Education Progress (NCES, 2001) has reported deficiencies in higher order reasoning skills, including those necessary for advanced reading, comprehension, math, and science. The National Assessment of Educational Progress's (NCES, 2001) most recent report found that only 5 percent of high school graduates could satisfactorily master material traditionally used at college level. Perhaps, it is no surprise that 80 percent of the books in the United States are read by about 10 percent of the people. Cullinen (1997) asked a group of typical fifth graders what percentage of time they spent outside of school reading. Fifty percent read 4 minutes a day or less; 30 percent read two minutes a day or less, and 10 percent read nothing. Cullinen remarked that our society is becoming increasingly "alliterate," meaning that people know how to read, but choose not to. Most alliterates watch television for their news and achieve only a superficial level of understanding. Healey (1990) cites a report of a survey of 443 students entering community college revealed that 50 percent were reading below ninth grade level. The *New York Times* reported in March, 1988 (*New York Times*, 1988), that youngsters may "sound out" words better than they used to, but are actually understanding less (cf. Pearson, 1986; Pappas and Brown, 1987; Kamil et al., 2000). Several of the teachers interviewed by Healy felt that children from every neighborhood come to class with fewer social skills, less language ability, less ability to listen, and less motor ability and that in general, a frightening majority of children's attention spans have degenerated over recent years. Objective support for these reported conclusions is supported in the literature by numerous studies (Woody-Ramsey and Miller, 1988; Ruff and Lawson, 1990). We conclude that sedentary lifestyles, increased television viewing, and busy parents are major causes of these dramatic statistical changes in cognitive, motor, and academic performance of present day western school aged children.

Recent estimates (Nelson, 2002) state that three quarters of all school age children and two thirds of pre-school children have mothers in the labor force. A large percentage of those children come home to a house without a parent or other adult. Fifty percent of those parents do not have adequate day care available to them. More than half of American 1 year olds are spending their days with someone other than their mothers. Additionally, English is frequently a second language for many daycare workers. Therefore, the children in their care are initially learning to speak English from non-English speaking adults. When parents are not around and the availability and quality of daycare are not standardized, the television, VCR, and video-computer games become the surrogate baby-sitter. These are sedentary activities, which tend to breed increasingly sedentary behavior. We will later outline why we think the most important factor in children's "changing brains" is lack of physical activity.

There has been a significant lifestyle change in the last two decades where rates of obesity among children and adolescents have jumped 45 percent between 1960 and the 1980s

(Campbell et al., 2001; Steinbeck, 2001; Child Health Alert, 2002). A number of studies (Barlow et al., 2000; Kiess et al., 2001; Morgan et al., 2002) have shown that a significant number of American children are overweight and cannot pass basic physical tests of strength, endurance, and agility. In 1984, only 2 percent of 18 million who took the presidential physical fitness test received an award. The American Academy of Pediatrics recently issued a report declaring that up to 50 percent of the nation's school children are not getting enough exercise to develop healthy hearts and lungs and that 40 percent of youngsters between ages 5 and 8 exhibit at least one risk factor for heart disease (Story et al., 2002). In 1989, the United States Army was forced to modify the physical requirements in basic training. Lt. Col. John Anderson was quoted as stating, "it's our opinion that the young people coming into the military now have spent more time in front of the television than on the tennis court or softball field." (*Associated Press*, April 18, 1989). Newsday (November 17, 1997) reported that Dr Pat Vehrs, an adolescent and health expert at Baylor College of Medicine and Texas Children's Hospital in Houston had said that children are increasing their body fat and decreasing their exercise time. "Children and teenagers are increasingly obese and are not as physically active as their counterparts in previous decades. National surveys have shown that since the 1960s, *but especially in the last decade* (italics ours), there has been an increase in the percentage of body fat and a decrease in physical activity among youth." Not coincidentally, it has been during the past decade that we have also seen a sharp increase in the percentage of children with learning disabilities, attention problems, and subsequently increased use of Ritalin. Vehrs claims that 21 percent of children aged 6–17 may be classified as obese. He believes that there are many reasons for this trend, among which are the following:

1. Parents who work may ask their children to stay at home alone until their parents return. This encourages inactivity by limiting children to indoor pursuits.
2. Family members may participate in few physical activities together. Often parents are too tired when they arrive home to walk, shoot baskets, or ride bicycles with their children.
3. Fear of neighborhood crime.
4. Lack of sidewalks, well-lit streets, access to parks, gyms, or pools in the suburbs.

Vehrs also commented, "Parents shouldn't be complacent because their children are taking physical education classes at school." Physical education classes usually last less than an hour a day. "By the time (the children have) changed clothes, gotten into the gym, and taken roll, there is very little actual time left." The same is true for children's weekend sports like soccer where the child spends more time actually standing around than doing any real continuous physical activity.

The reasons that Vehrs provides for increasing obesity in childhood are the same reasons teachers give for decreased verbal and reading scores, and increases in sustaining attention. There seems to be a connection between the two, that decreased physical activity is related in some way to decreased efficiency of brain function and decreased scholastic and behavioral performance. Healey (1990) poses the question, "If young bodies are in bad shape, what about the brains attached to them."

Surprisingly, we know little about the relationship between motor performance and physical exercise on the one hand, and school success motivation, and subsequent abilities to concentrate on the other. Surprisingly, there are few studies in the literature that have explored the effects of a sedentary behavior on the child's capacity to learn.

We intend to thoroughly explore this relationship between motor activities and learning. We will examine the relationship between less physically active children and increased brain dysfunction. Studies examining alterations of neurochemistry, and clinical outcome studies are not sufficient to explain the measured and reported changes in child classroom behavior. While a significant portion of

the explained variance of neurobehavioral disorders of childhood that affect learning ability has a genetic component affecting the child's neurochemistry, we posit that environmental factors are as significant in explaining and in possibly remediating this class of disorders. While it may be accurate that neurotransmitter function may be altered in some way in neurobehaviorally involved children but not necessarily because these chemicals cannot be adequately produced or because they are unbalanced. Neurotransmitters are simply messengers; the problem is more likely based with the message rather than with the messenger.

Current theory and approaches to treatment of neurobehavioral disorders in childhood are failing. We do require some comprehensive theory to account for these increasingly frequent disorders of childhood that can be translated into meaningful strategies for better addressing management at home and in school.

We first started to conceive of the text as an overview of attention deficit hyperactivity disorder. In the literature, and in the practices of numerous Education and Behavioral specialists we have been noting a more rapid increase of *autistic spectrum disorder*s.

Before even beginning to speculate about commonalities in various neurobehavioral disorders, we have noticed both in the literature and in clinical practices that there seems to be a high rate of comorbidity between *ADHD* and *autism* (Bonde, 2000; Luteijn et al., 2000; Richardson and Ross, 2000; Noterdaeme et al., 2001) and other disorders such as *obsessive–compulsive disorder*, *Tourette's* syndrome, learning disability, dyslexia, *pervasive developmental disorder*, and *Asperger's* syndrome (Adesman, 1996; Gartner et al., 1997; Ghaziuddin et al., 1998; Bonde, 2000; Kadesjo and Gillberg, 2000). Many studies have found that over 50 percent of children diagnosed with an ADD, also meet the diagnostic criteria for one or more additional psychiatric disorders such as mood, anxiety, substance abuse, learning, or behavior disorders (Gartner et al., 1997; Ghaziuddin et al., 1998; Gralton et al., 1998; Bonde, 2000; Dykens, 2000; Kadesjo and Gillberg, 2000). It seems unlikely that a child would have two or three different psychiatric conditions simultaneously. Many experts theorize that the comorbidity of these conditions exist because these disorders have similar underlying genotypes, although there is no evidence to support such a contention at present. In *Tourette's* syndrome, the early developmental manifestations include not the characteristic vocal tics but rather the diagnosis of *ADHD* (Thomsen, 2000; Cohen, 2001; State et al., 2001; Zappella, 2002). Well then why is it not diagnosed as *ADHD* with a vocal tic rather than a whole separate diagnosis? If all of these conditions are usually present together in one child perhaps, they are really all in the same condition. We believe that this in fact is the case. Many researchers no longer look at these disorders as discrete separate conditions but rather *comorbidities*.

COMORBIDITIES OF NEUROBEHAVIORAL DISORDERS OF CHILDHOOD

Many researchers no longer look at these disorders as a discrete separate condition, but rather as a spectrum of disorders. They are more frequently being viewed as related clusters, spectrum, or dimensional groupings of slightly varying dysfunctions of a related functional system. Examples include Schizophrenic Spectrum Disorder (Bellak, 1994), Compulsive–Impulsive Spectrum Disorders (Oldham et al., 1996), *autistic spectrum disorder* (Towbin, 1994), and *depressive spectrum disorders* (Angst and Merikangas, 1997).

ADD/ADHD

Tannock and Schachar (1996) note, "that there is a growing consensus that the fundamental problems in (*ADHD*) are in self-regulation and that *ADHD* is better conceptualized as an impairment of higher-order cognitive processing known as (executive function)."

Castellnnos (1999) also noted that "unifying abstraction that currently best encompasses

the faculties principally affected in *ADHD* has been termed executive function (EF) which is an evolving concept. ... There is no impressive empirical support for its importance in *ADHD*." What is clear in the literature is that the main functions that are affected have been termed executive functions and it is known that executive functions seem to primarily reside in the *frontal lobes*. In fact, *ADD* is considered a name for a spectrum of deficits of cognitive executive functions that may respond to similar treatments and are often comorbid with a wide variety of psychiatric disorders, many of which may also be spectrum disorders.

According to Brown (1991), this view of *ADD* as a cluster of attentional/executive impairments that appear and may persist with or without psychiatric comorbidity is consistent with Seidmans' findings from neuropsychological testing of children and adults with *ADD* (Seidman et al., 1995a, 1995b, 1997a, 1997b, 1998).

Hudziak and Todd (1993) also noted that the rates of comorbidity in children for *ADHD* and ODD was 35 percent, CD was 50 percent, mood disorders 15–75 percent, anxiety disorder 25 percent, and learning disabilities 10–92 percent. It has also been noted that individuals with ADD have a significantly increased probability of having increasingly additional psychiatric disorders (Biederman, J. et al., 1991; Jensen et al., 1997).

Learning Disabilities

Although the relationship between learning disabilities and *ADD* is not well understood, there is nonetheless significant resource that shows significant elevation of specific learning disorders such as reading disorder, math disorder, and disorders of written expression in individuals who are diagnosed with *ADD* (Cantwell and Baker, 1991).

Obsessive–Compulsive Disorder (OCD)

Numerous authors have noted varying degrees of overlap between *OCD* and *ADHD*. Percentage overlaps range from 6 percent (Toro et al., 1992) up to 32 percent and 33 percent (Geller et al., 1995, 1996) respectively.

Tourette's Syndrome

Most studies developmentally examining *Tourette's* syndrome and its comorbidity with *ADHD* demonstrate that between 25 and 85 percent of *Tourette's* syndrome probands have comorbid *ADHD* or *ADD* (Comings and Comings, 1984, 1985, 1986, 1987, 1988, 1998; Shapiro et al., 1988). Another interesting finding is that in *Tourette's* syndrome, as the severity of symptoms increases, the frequency of comorbid *ADD* also increases. It has also been noted that the combined prevalence of *Tourette's* syndrome in males was 1 in 1,400 and that males with *Tourette's* syndrome 27 percent had *ADHD*, 27 percent had sleep disorders, 17 percent had conduct disorders, 7 percent had *obsessive-compulsive disorder*, 27 percent had repeated a grade, and 24 percent had learning disorder (Caine et al., 1998). As we had noted earlier, the first signs of *Tourette's* syndrome are not necessarily vocal tics, but rather the diagnosis of *ADHD*.

Pervasive Developmental Disorder (PDD)

It has been noted that there also is a relationship between *ADD* and severe *autistic* and/or schizophrenic spectrum disorders (Luteijn et al., 2000). Luteijn and colleagues examined differences and similarities between social behavior problems in children with problems classified as *pervasive developmental disorder* not otherwise specified (*PDD-NOS*) and a group of children with problems classified as *ADHD*, as measured by parent questionnaires. In comparing the *PDD-NOS* group and the *ADHD* group, the results demonstrated that both groups have severe problems in executing appropriate social behavior. The two groups could be distinguished only by the nature and the extent of these problems. Roeyers and colleagues (1998) also investigated early clinical differences between children with a diagnosis of *PDD-NOS* and

children with *ADHD*. A differential diagnosis between the two disorders is often difficult in infancy or early childhood. Twenty-seven children with *PDD-NOS* were matched with 27 children with *ADHD* as to IQ and chronological age. Their parents were retrospectively questioned on pre-, peri-, and postnatal complications and on atypical or delayed development of the children between 0 and 4 years of age. This exploratory study revealed almost no differences between both groups with respect to pregnancy or birth complications.

Autism/Asperger's Syndrome

The similarities between the symptoms and *autistic spectrum disorder*s are actually significant when one looks at the symptoms associated with *ADHD*. In fact, when we examine them, they seem almost identical. It has been noted that *autistic* individuals maybe hyperactive, but that they also present with executive dysfunction in attention, impulsivity, and distractibility. It has also been noted that there is a similarity between *autistic* disorder and *Asperger's* syndrome and that *Asperger's* syndrome goes under many different types of names, some of the names are semantic-pragmatic disorder, right hemisphere learning disability, nonverbal learning disability, and schizoid disorder.

Much of this confusion has come about by the way we diagnose these problems. We would like to believe that there is a lab test or an objective test somewhere that confirms the diagnosis of *ADHD*, *OCD*, or *Tourette's*; but in fact, the diagnosis is purely subjective. There are no consistent anatomic or physical markers for these conditions. Most often, these disorders are diagnosed by a professional sitting down with a parent or teacher and reading to them a list of symptoms and checking off if the parent or teacher believes that the child manifests the relevant symptoms. However, even this process is not as clear-cut as it sounds. The list of symptoms is extremely vague and many of these conditions are hard if not impossible to distinguish.

One problem, according to Linda Lotspeich (Lotspeich and Ciaranello, 1993; personal communication, 2001), Director of the Stanford *Pervasive Developmental Disorder*s Clinic, is that the rules in the *DSM-IV* do not work. "The diagnostic criteria are subjective, like marked impairment in the use of nonverbal behaviors such as eye-to-eye gaze, facial expression, body posture, and gestures to regulate social interaction." "How much 'eye-to-eye gaze' do you have to have to be normal?" asks Lotspeich. "How do you define what 'marked' is? in shades of gray, when does black become white? What is happening is that a group of symptoms is being called a disorder and if we add or subtract a few symptoms or make a few more severe, then it is called a different condition or syndrome. However, when we look at the areas of the brain involved in all of these conditions, and the neurotransmitter systems involved, they are all basically the same. Therefore, in reality, these are all possibly the same problem along a spectrum of severity. The most common of all comorbidities is *OCD*, developmental coordination disorder or more simply put "clumsiness" or motor incoordination. In fact, practically all children in this spectrum have some degree of motor incoordination. The type of incoordination is also usually the same. It involves primarily the muscles that control gait and posture or gross motor activity. Sometimes to a lesser degree, we find fine motor coordination also affected. Although it has been fairly well known that attention deficit disorders are comorbid with psychiatric disorders such as the ones described above, what is less known and what is more significant is the association between *ADD* and motor controlled dysfunction (clumsiness) or what has been termed as developmental coordination disorder (*American Psychiatric Association*, 1994). In the past, motor clumsiness or *OCD* have not been looked at as being psychiatric in nature, but rather being neurological and falling more under the realm of the pediatric neurologist. Motor control problems were first noted in what was then called the minimal brain dysfunction syndromes or MBD. Minimal Brain

dysfunction was the term denoting children who had normal intelligence, but who had comorbidity of attention deficit and motor dysfunction or "soft" neurological signs.

Several studies by Denckla and others (Denckla and Rudel, 1978; Gillberg et al., 1982, 1993; Denckla et al., 1985; Wolffet et al., 1990; Landgren et al., 1996; Kadesjo and Gillberg, 1998) have shown that comorbidity exists between *ADHD* and *OCD*, dyscoordination or motor perceptual dysfunction. Several Swedish studies have shown that 50 percent of children with *ADHD* also had *OCD* (Brown, 2001).

In a Dutch study (Hadders-Algra and Towen, 1992), 15 percent of school age children were judged to have mild minor neural developmental deviations and another 6 percent demonstrated severe neural developmental deviations (occurring in boys twice as often as in girls). Minor developmental deviations were noted to consist of dyscoordination, fine motor deviations, choreiform movements, and abnormalities of muscle tone. Researches that have dealt with these minor neural developmental deviations tend to look at motor dysfunction as a sign of neurological disorder that may be associated with other problems such as language and perception dysfunction. Motor dyscoordination has also been noted as a significant sign in *autistic spectrum disorder*s and in *Asperger's* syndrome. In fact, it has been speculated that the type of motor incoordination might be able to differentiate high functioning *autistic* HSA individuals from *Asperger's* syndrome individuals (Gepner and Mestre, 2002; Green et al., 2002; Rutherford et al., 2002). In *Asperger's* syndrome, it has been noted that individual's have significant degrees of motor incoordination. In fact, in Wing's original paper, she noted that the 34 cases that she had diagnosed based on *Asperger's* description, "90 percent were poor at games involving motor skill, and sometimes the executive problems affect their ability to write or draw." Although, gross motor skills are most frequently affected, fine motor and specifically graphomotor skills were sometimes considered significant in *Asperger's* syndrome" (Wing and Attwood, 1987; Wing, 1988).

Wing (1981) noted that posture, gait, and gesture incoordination was most often seen in *Asperger's* syndrome and that children with classic *autism* seem not to have the same degree of balance and gross motor skill deficits. However, it was also noted that the agility and gross motor skills in children with *autism* seem to decrease as they get older and may eventually present in similar or at the same level as *Asperger's* syndrome.

Gillberg (1989) reported clumsiness to be almost universal among children that she had examined for *Asperger's* syndrome. The other symptoms she noted that were associated with *Asperger's* syndrome consisted of severe impairment and social interaction difficulties, preoccupation with a topic, reliance on routines, pedantic language, comprehension, and dysfunction of nonverbal communication. In subsequent work, Gillberg included clumsiness as an essential diagnostic feature of *Asperger's* syndrome (Gillberg and Gillberg, 1989; Ehlers and Gillberg, 1993).

Tantam (1991) noted that 91 percent of the *Asperger's* individuals in his study were deemed clumsy and he reported that the most significant difference between *Asperger's* and non-*Asperger's* individuals was that ball catching was significantly poor in *Asperger's* individuals. Kline and colleagues (1995) noted that a significantly higher percentage of *Asperger's* rather than non-*Asperger's autistic* individuals showed deficits in both fine and gross motor skills either relative to norms or by clinical judgment. They further noted that all 21 *Asperger's* cases showed gross motor skill deficits, but 19 of these also had impairment in manual dexterity which seem to suggest that poor coordination was a general characteristic of *Asperger's*. With studies like this, many researchers have looked at fine motor coordinative skills as being disrupted as a general feature of *autistic spectrum disorder*s. However, when we examine the condition from a hemispheric perspective, as we will note later, gross motor skill dysfunctions are more typical of right hemisphere involvement whereas fine motor skill dysfunctions are more typical of left hemisphere involvement. We will demonstrate later that both classic *autism*

and *Asperger's syndrome* are associated with right hemisphere deficits, and thereby, would be expected to show a greater involvement of gross motor skill deficits. It might seem somewhat confusing initially when fine motor skills seem to be disrupted at almost equal levels. According to a neuropsychological model, this type of weakness would be more indicative of a left hemisphere deficit. However, when examining the literature closely, it has been noted (Szatmari et al., 1990) that manual dexterity is less effective for high functioning *autistic*s than for *Asperger's*, but only for the nondominant hand. This suggests a lateralized difference. This would show that although fine motor coordinative skill is decreased, it is decreased in the left hand more specifically, which is associated with right hemisphere function. This is consistent with a hemispheric imbalance model and specifically a right hemisphericity.

Manjiviona and Prior (1995) noted that 50 percent of *autistics* and 67 percent of their *Asperger's* group presented with significant motor impairment as defined by norms on a test of motor impairment. However, the two *autistic* subgroups did not differ significantly.

Szatmari and colleagues (1990) also noted that *autistic* groups did not differ from *Asperger's* groups with respect to dominant hand speeds on type boards although both were slower than psychiatric controls. Vilensky and associates (1981) analyzed the gait pattern of a group of children with *autism*. They used film records and identified gait abnormalities in these children that were not observed in a controlled group of normally developing children or in small groups of "hyperactive/aggressive children." Reported abnormalities were noted to be similar to those associated with *Parkinson's*. Hallet and colleagues (1993) assessed the gait of five high functioning adults with *autism* compared with age matched normal controls. Using a computer assisted video kinematic technique, they found that gait was atypical in these individuals. The authors noted that the overall clinical findings were consistent with a *cerebellar* rather than a basal ganglionic dysfunction.

Kohen-Raz and colleagues (1992) noted that postural control of children with *autism* differs from that of matched mentally handicapped and normally developing children and from adults with vestibular pathology. These objective measures were obtained using a computerized posturographic technique. It has been also noted that the pattern of atypical postures in children with *autism* is more consistent with a mesocortical or *cerebellar* rather than vestibular pathology. Numerous investigators (Howard et al., 2000) have shown independently empirical evidence that basic disturbances of the motor systems of individuals with *autism* are especially involved in postural and lower limb motor control.

THE *DOPAMINE* CONNECTION

Neural substrates, which may be especially important in executive function, working memory, and *ADD*, are those of the nigro*striatal* structures. Crinella and associates (1997) reported findings from organism studies suggesting that nigro*striatal* structures contribute essential, superordinate control of functions such as shifting mental set, planning action, and sequencing (i.e., executive functions). As Pennington and colleagues (1996) pointed out, many developmental disorders may result from a general change in some aspect of brain development such as neuronal number, structure, connectivity, neurochemistry, or metabolism. Such a general change could have a differential impact across different domains of cognition, with more complex aspects of cognition, such as executive functions, being most vulnerable and other aspects being less vulnerable. In this same context, Pennington and colleagues noted that the executive function impairments associated with *ADHD* and some other developmental disorders may all involve varying degrees of *dopamine* depletion in the *prefrontal* cortex and in related areas (p. 330).

In a review of findings from neuroimaging studies of the human brain, Posner and Raichle (1994, pp. 154–179) showed evidence of at least three anatomic networks that function

separately and together to support various aspects of attention. The possibility that attention impairments resulting from *ADD* may be closely related to *dopamine* decreases in certain areas of the brain finds support in the numerous studies that have demonstrated *dopaminergic* medications (e.g., *methylphenidate*, *dextroamphetamine*) to be effective in alleviating a wide variety of inattention symptoms (see Levy, 1991). Although *noradrenergic* medications (e.g., *desipramine*, *nortriptyline*) and alpha2-agonist medications (e.g., *clonidine*, *guanfadine*) have been demonstrated to be effective in alleviating hyperactivity–impulsivity symptoms of *ADHD*, there is some evidence that these nonstimulant medications are less effective in alleviating inattention symptoms (Spencer et al., 1996; Levy and Hobbes, 1988; *American Academy of Child and Adolescent Psychiatry*, 1997). These findings suggest that a specific neurotransmitter system, the *dopaminergic* system, may play a particularly important role in inattention symptoms of *ADD*. Servan-Schreiber and associates (1998) summarized the research literature on the impact of *dopamine* on specific neural networks in human information processing. They developed and tested a model demonstrating that *dopamine* has a direct positive effect on the gain in the activation function of the neural networks underlying attentional processing. Additional evidence for the critical role of *dopamine* in management of cognition comes from recent laboratory studies summarized by Wickelgren (1997), which indicate that in many species *dopamine* plays a critical role in mobilizing attention, facilitating learning, and motivating behavior that is critical for adaptation. The role of *dopamine* in facilitating these functions may be far broader, subtle, and complex than had previously been thought. Inattention symptoms of *ADD* may be reflecting impairments resulting primarily from insufficient functioning of aspects of *dopaminergic* transmission in the human brain.

What is the connection between the motor and the cognitive/emotional systems? In the past, motor areas of the brain were thought to be distinct from areas that control cognitive functions. However, over the last few years, those lines have blurred significantly and it is now recognized that areas like the *cerebellum* and the *basal ganglia* influence both motor function and nonmotor function as well. Motor and cognitive functions are closely related. In fact, it is thought that cognitive function, or what we call thinking, is the internalization of movement and that cognition and movement are really the same. We will attempt to better understand the connection between motor control, cognition, and posture and how these connectivities may be involved in learning and its dysfunction as well as in neurobehavioral disorders of childhood.

To fully understand the connection between motor and cognitive function and how they are connected in dysfunctioning systems we will examine these processes in evolutionary terms. We will explore the evolution of movement and how it relates to the evolution of nervous systems and ultimately brains and in particular the human brain. There are three elements that are important in facilitating an understanding of the growth of the human brain: (1) environmental stimulus and its effects on the brain, (2) plasticity, and (3) Darwin's theory of natural selection. With these three elements better understood, we can better understand why and how the human brain developed as it did.

2

Evolution of the Human Brain

EVOLUTIONARY PERSPECTIVES

"Nothing in biology makes sense except in the light evolution ..." says Theodosius Dobzhansky, distinguished geneticist in Scientific American (Ewald, 1993). "Evolutionary biology is, of course, the scientific foundation for all biology, and biology is the foundation for all medicine. To a surprising degree, however, evolutionary biology is just now being recognized as a basic medical science .... The enterprise of studying medical problems in an evolutionary context has been termed *Darwinian medicine* .... Darwinian medicine asks why the body is designed in a way that makes us all vulnerable to problems like cancer, atherosclerosis, depression, and choking, thus offering a broader context in which to do research."

Modern science tells us that the earth was formed approximately 4.5 billion years ago. It is also thought that life started on earth about 3.85 billion years ago. How it started is still a mystery but it is thought that a microbe either arose spontaneously on earth, or was transported from space. However, either way life started with simple single cell creatures or *prokaryotes* and eventually *eukaryotes*. From there, life developed in the salty oceans and the first multicellular creatures were thought to be sessile and more plant-like. They were implanted on the floor of the ocean and would filter-feed, they did not move. However, it is thought that through a process known as *paedogenesis*, the foundation of vertebrates was formed. *Paedogenesis* is the process whereby the larval form of a creature becomes sexually active and thereby reproduces at that stage of development. This is what is thought to have happened several billion years ago. We can use a sessile creature such as a sea squirt as an example of how this may have occurred. Sessile creatures like the sea squirt were probably some of the earliest forms of life. These organisms do not actually have a nervous system so to speak; they have a primitive nerve net. However, the larval form of the sea squirt has a very different appearance. It resembles a tadpole. It has a muscular tail, a primitive *notochord*, and a form of nervous system, and brain. What happens in the sea squirt is that once the larva is formed it swims around and finds a hospitable place to feed and implant itself into the ground, the tail and nervous system dissolve and the creature becomes sessile once again without a nervous system. The lesson we learn from this is that a brain and nervous system is only necessary in moving creatures.

R. Melillo and G. Leisman, *Neurobehavioral Disorders of Childhood: An Evolutionary Perspective*,
DOI 10.1007/978-1-4419-1231-2_2,

What is thought to have happened is that at some point, this larval form became sexually active and reproduced at that stage and life on earth was never the same. This scenario is very feasible. In fact, 70 percent of evolution is thought to have happened by the addition of a step in the beginning or subtraction of a step from the end of the development of the organism thereby creating a different form. The late Steven J. Gould thought that this is because there are different timing mechanisms for development in organisms. He thought that there are separate timing mechanisms for sexual and physical development and one may slow down or speed up while the other remains the same. By the time an organism reaches sexual maturity and stops developing, it may have achieved only the body plan of a juvenile ancestor. Alternatively, an organism may go through the entire development of its forerunners while it is still young and then simply continue the program, growing bigger horns, or more shell coils. Researchers now think that there are many different timers in a single organism, each controlling the growth of a step (Soll, 1983; Lloyd and Edwards, 1987). It has been speculated that the retardation of the development of the skull may have been connected with an expanded period of neuroblast proliferation in the cerebral cortex thereby increasing cell number (Noden, 1992). In this larva form, the sexually matured mechanism sped up allowing it to reproduce while the physical mechanism remained unchanged. Most importantly, we see that the brain was born out of movement. Even though these creatures could now move and swim all over, they still were filter-feeders.

The next major step in evolution occurred with the development of biting jaws, arising from modified gills and denticles. Armed with jaws, organisms were now free to roam anywhere in search of food and were no longer lowly bottom feeders. This further increased mobility and allowed creatures to inhabit, not only seas and oceans but also fresh water streams and rivers. As a result of frequent periods of drought throughout the world, fish inhabiting these streams and rivers would see these bodies of water significantly reduced in size and the oxygen content become dangerously low. Organisms that could develop an alternate source of respiration would be better fitted for survival and we know that some fish developed primitive lungs and were able to breathe air. A further stage in evolution was the development of the typical vertebrate shape, the development of pectoral and pelvic fins, and the lateral swim line. With more sophisticated movement, we see the development of a brain to control that movement and the first appearance of the *cerebellum*. Some organisms developed the pectoral and pelvic fins further to move around in the bottom of the water by means of fleshy lobed fins. These also provided an advantage during times of drought. When streams and ponds dried up and the oxygen content was low, fish with fleshy lobed fins and lungs could skirt along the land to another pond or stream and thereby enter that stream and survive. Although we start to see the ability to move on land, it was not until sometime later after insects proliferated and there was a food source on land that we see a development of amphibians.

This first part-time land dwellers had to be able to move equally as well in land and water so they maintained the basic shape of fish for movement. The midline trunk muscles provided the main thrust with oscillations back and forth. The limbs were used as mere anchors to pull forward. Eventually the limbs were adducted and were placed under the organism more often. This allowed the organism to easily lift itself off the ground reducing friction and allowing the organism to move quickly improving its ability to hunt, prey, or retreat from predators. It also allowed better respiratory function allowing the ribs to expand more efficiently and provided the organism with more oxygen to improve endurance. This also increased the available oxygen for the organism's brain, which is critical for brain growth especially in the areas of the *cerebellum* and cortex, which use the most oxygen. With the *thecodonts*, there developed true locomotion with a trend toward bipedalism. From the *thecodonts* developed the bipedal dinosaur and pterosaurs, the bird

ancestors. It is thought that these organisms first became arboreal before they developed flight with a probable intermediate stage of gliding.

Although reptiles were the ancestors of mammals there was an early split close in time to the development of the class. As early as the *Pennsylvanian era*, there is evidence of the existence of a distinct line leading to the development of mammals (MacLean, 1985). This early stock consisted of the *synapsids*, which led to the more advanced *therapsids*. These were mammal-like reptiles with a marked change in locomotion. Their elbows were turned back and the knees turned forward. The arms were placed almost directly under the body where their weight was supported by the bones rather than by continuous muscular effort. This conserved energy and allowed for longer strides. With this limb structure, *therapsids* resembled the limb structure of mammals. It is thought that temperature regulation was more advanced in these creatures, and scales were replaced by hair. However, there does not appear to be an increase in brain size characteristic of mammals. *Therapsids* were dominant in later *Permian* and early *Triassic* times. In the later *Triassic era*, however, we see a sharp reduction in *therapsids* with only a scarce few remaining. Apparently, the ruling reptiles, possibly due to the development of bipedalism as a more efficient form of locomotion, temporarily overtook *therapsids*.

The *Jurassic* and *Cretaceous* periods belong to the dinosaurs while *therapsids* disappeared; however, they left behind descendants, which would once again eventually dominate as mammals. It is thought that the main characteristic that was unique to mammals was intelligence. In mammals, we also see the retention of the advanced locomotor activity of the *therapsids* with further development of a more efficient temperature regulation mechanism. Advanced mammals began domination again after the late cretaceous extinction of the dinosaurs and are most notable for the size and complexity of their brain. It is also thought that improvements in the reproduction of mammals are related to allowing the brain as long a time as possible to reach maturity before being used most efficiently. The retention of the embryo and the fetus in the mother for a longer period was a major step toward this end. Also, development of a nursing habit is thought to not only postpone the time when the youngster must go it alone, but also allows for a period of training to take place. Eventually, we see the development of small primates, similar to lemurs, which were mostly arboreal at the time. The development of *brachiation* also was an advanced form of locomotion, which would also require accompanying cognitive advances in hand–eye coordination and in predictive ability. We then see the development of advanced primates, which appear to have had an arboreal and partly bipedal existence, which has been postulated to exist in *Australopithecus* and *Paranthropus* species, the species that predate hominids.

Eventually, this development progressed further and produced various species of primates that were primarily tree-dwelling creatures. It was previously thought that approximately five million years ago with the beginning of the ice age, certain catastrophic environmental changes occurred in Southeast Africa, which destroyed most of the forests and left the *Australopithecus* in its wake. The story goes that some inhabitants stayed in trees and developed into chimpanzees and some were forced to remain on the ground. It was also previously thought that the first being known to walk upright was *Australopithecus afarensis* or Lucy, who was thought to have appeared about three or four million years ago. She was thought to have been the first bipedal primate. However, in 2001, it was reported (Haile-Selassie, 2001) that a graduate student named Yohannes Haile-Selassie had found what appeared to be the most ancient human ancestor ever discovered. It was a chimp-size creature that lived in the Ethiopian forest between 5.8 and 5.2 million years ago, which is nearly $1-\frac{1}{2}$ million years earlier than the previous Lucy. This new human ancestor had been listed as a subspecies variant of *Ramidus*, and has been given the name of *Ardipithecus ramidus kadabba*. One

of the unique features of *Kadabba* is that it is thought to have walked upright much of the time. Although it is also thought that it probably spent some time in trees. It is thought that this creature lived in large social groups that would include both sexes.

Paleontologists have suspected for nearly 200 years that bipedalism was probably the key to the evolutionary transition that split the human line off from the apes. Fossil discoveries as far back as *Java Man* in the 1890s supported this belief. However, as is typical in this rapidly changing evolutionary environment, in July, 2002 it was reported that an even older hominid species was found. This new species named *Sahelanthropus tchadensis* was found by French paleontologist Michael Brunet and his team in the central African region of Chad (Brunet et al., 2002). This species is thought to be between 6 and 7 million years old and is thought to be the oldest known bipedal hominid species. This is also thought to be close to the time when humans and chimps first separated in evolution, a finding making things somewhat more confusing as the circumstances under which bipedalism was thought to have arisen has changed from the previously held view.

It had been thought that as Africa became significantly drier, the grasslands favored bipedalism so that early hominids could see over tall grasses to spot potential predators. Bipedalism, it is thought, also would have allowed the dissipation of heat from the grassland sun. However, this recent find changes these theories because, as it turns out, the earliest humans may have not developed in grasslands at all. In a companion paper to the one published in July, 2001 in *Nature* (Vignaud et al., 2002), it is reported that the most recent *Ardipithecus ramidus kadabba* and *Sahelanthropus tchadensis*, as did other then contemporary ancient hominids, all lived in a well-forested environment. At this time, scientists do not understand what the main advantage to walking upright was. According to evolution, we now have a picture of how human development may have progressed. About 6–7 million years ago, we have the newest member of the hominid species *Shadantropus tchadereniss* then approximately 5.8 million years ago, the *Ardipithecus ramidus kadabba*. Then, a million years later, its descendent, the renamed *Ardipithecus ramidus* appears. After that arises a new genus, *Australopithecus*, where Lucy belongs and it is only about two million years ago that the first member of the human genus *homo* arises. For most of the past six million years, multiple hominid species roamed the earth until approximately 30,000 years ago when modern humans and neantherdals coexisted.

Overall, these new findings raise the question as to the main advantage of bipedalism. We believe bipedalism to be associated not with the biomechanical or social development of *Homo sapiens*, but rather with changes in the development of man's nervous system that occurred because of walking upright. Nevertheless, before we explore this further let us understand the mechanics of walking.

The Mechanics of Walking

From a biomechanical perspective, Lovejoy and colleagues (1982), contend that the advantages of walking upright were somehow so great that the behavior endured throughout thousands of generations. It is well known that the anatomy of our ancestors underwent all sorts of basic changes to accommodate bipedalism. Some of these changes helped the body stay balanced by stabilizing the weight-bearing leg and in keeping the upper torso centered over the feet. Much of the changes associated with bipedalism may have improved coordination as well. They state "to walk upright in an habitual way you have to do so in synchrony." They state further, "if the ligaments and muscles are out of sync, that leads to injuries and then you would be chetah-meat." In addition, according to Lovejoy, by far the most crucial changes were those in the spine. The distance between the chest and pelvis is longer in humans than apes allowing the lower spine to curve, which locates the upper body over the pelvis for balance. This is an interesting statement when we understand that the main basis of consciousness itself, which is thought to be developed uniquely in

the human brain and possibly as a byproduct of bipedalism, are the oscillations that occur in the brain and the ability to keep the brain in synchrony due to these oscillations (cf. see Leisman, 1976a; Koch and Leisman, 1990). It is also important that one half of our brain be in synchrony or coherent with the other and that possibly bipedalism may have helped to create such an environment in the brain.

In evolution, the laws of biomechanics are simple. Two factors determine adaptation. One is safety and the second is the conservation of energy. This means that biomechanically, if an adaptation is safe and more energy efficient, it will most likely be selected. Walking and standing upright, both fit these criteria. Bipedal walking is efficient; it uses two limbs instead of four, and in doing so conserves energy. We can still run over a short distance as fast as some organisms with four legs. There are stories of American Indians, for example, being able to chase and catch horses on foot. Bipedalism did not compromise our speed or agility to hunt. We can swim and climb trees. Our hands are freed to make tools and allow greater mobility to search for food in distant locations. Humans have been hunter–gatherers for 99 percent of their history, so the physical adaptation to hunt and gather mechanically makes the most sense. From a biomechanical standpoint, the key to standing and walking upright involves the architecture of the spine.

During the evolution of erect posture, the lumbar or lower back joints, and the lumbosacral joints developed the ability to achieve a position of pronounced extension. This allows for a marked lumbar curvature or *lordosis* of the spinal column. This curve is present and developed not only in the lower back, but also in the neck. This adaptation puts the spine and head in an upright position. Except for the tailbone or sacrum, the spinal column has no curves at birth. The thoracic or mid-back part of the spine gradually develops a relatively fixed curve in the young child. A flexible cervical or neck curve appears when the infant is able to raise its head.

The flexible lumbar curve or lower back curve appears at the end of the first year when the child starts to walk. The lower back curve is necessary to obtain the erect posture because the pelvis remains essentially in the same position as that in standing all fours in the quadruped position. The fact that the pelvis did not shift from its quadruped position during evolution of the erect posture also necessitated placing the hip and knee joints into full extension.

Additionally, the arch of the foot developed so that the bones are structurally arranged to support the body weight with reduced muscular activity. In humans, where the ligaments are passive and do not use energy, the bones and fully extended hip and knee joints bear the brunt of the forces involved in standing erect. Only humans stand perfectly erect. Quadrupeds, including knuckle-walking apes can mimic the human erect posture. However, they do this with a great expenditure of energy because their hips and knee joints cannot be fully extended; extended so that the passive ligaments and joints can withstand the forces involved in standing erect.

Evolution must be energy efficient or it will not proceed optimally. We see this same expenditure of energy when a child first starts to stand with partially flexed hips and knee joints. An erect posture appears to be most awkward when compared to a quadrupedal posture; however, it is the most efficient and economic posture to have evolved. Once man rose by muscular activity to attain the fully erect position, the contraction of small "postural" muscles in the spine, hips, and legs are required to keep the head, trunk, and limbs aligned vertically in line with the center of gravity. Evolving to this position took some effort.

The driving force behind the spinal curve and the changes in the hip and knee joints are muscular activity. The physiological principle known as *Wolfe's Law* states that bone or connective tissue will adapt based on the forces that are applied to it. Those forces are generally muscles and gravity. The contraction or activation of muscle would have had to promote an upright posture, and relaxation or inhibition of muscle would have been required to promote a quadrupedal position. We think that these principles are associated