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## SPECIAL ARTICLE

# American Pediatric Society Presidential Address 2005: Pediatric Scientists Priming The Pipeline

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Thank you for allowing me the distinct honor of serving as the 116th President of the American Pediatric Society (APS). Since initially attending the academic societies' meetings in the late 1960s, I have felt reverence for our societies, for our members, and for our collective resolve that children will be ever healthier as a result of our academic missions.

There is a vanishing number of physician scientists (1,2). We do not have enough pediatricians trained as both clinicians and investigators to "translate" science into improved clinical care at this remarkable time when the science is so rich and the hope derived from applying this science to the improvement of children's health is so promising. We must continue our resolve to address the challenge of increasing the number of productive pediatric scientists.

The thesis for this presentation is that new strategies are needed to attract more young people into scientific careers, preferably pediatric scientific careers. As pediatricians, we are at the forefront of understanding human development and of creating strategies to maximize children's potential. Remarkable data about the adolescent brain and adolescent behavior could be an impetus for us to be actively engaged early in "priming the pipeline" by utilizing our understanding of adolescent development and by joining with our educational colleagues in our communities to introduce substantive science education early to adolescents.

## THE PIPELINE

The American Board of Pediatrics tracks the percentage of pediatric residents in sub-specialty fellowships. (Presently, general academic pediatric fellows are not board subspecialty-eligible.) Data for first-time applicants for subspecialty boards are an approximation of potential pediatric scientists graduating from our training programs; we acknowledge that not all applicants for subspecialty boards will be successful pediatric scientists.

Table 1 shows the percentage of first-time applicants by year for the general pediatrics' examination selecting subspecialty careers. From 1990 to 1998, there was a decrease in the percentage of first-time applicants for pediatric subspecialty boards from a peak in 1990 of 33% to a trough of 20% in 1998 (3). Recently there has been a gradual increase in both the percentage of and in the number of applicants. In 2004, 25% of first-time applicants selected subspecialty career areas. Additionally, the current cohort of pediatric sub-specialists is aging. The average age is youngest (46.2 y) in pediatric emergency medicine and pediatric critical care; the average age is oldest (54.3 y) in pediatric nephrology (4).

There have been several successful interventions, led by members of our academic pediatric societies, to increase the number of and the quality of pediatric trainees pursuing scientific careers. Two such highly successful programs are the Pediatric Scientist Development Program (PSDP) and the Society for Pediatric Research/American Pediatric Society (SPR/APS) Student Research Program.

There have been 107 graduates of the PSDP from the classes entering between 1987–2002, of whom 36% have been women. Ninety-four percent are now faculty members in academic pediatric departments. Thirty-nine percent entering PSDP between 1987–2000 have been principal investigators on 78 National Institutes of Health grants. There have been more than 70 foundation grants and greater than 500 publications among the 107 graduates. (Hostetter M. 2005, personal communication)

The SPR/APS Student Research Program offers a rich program for gifted medical students. There are 300 laboratories in the United States and in Canada in which medical students, who are interested in pediatrics, can study. The medical school where the research is done must be at one other than the applicant's. (Anagnostelis B, 2005 personal communication)

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**Table 1.** *Percentage of first-time applicants for general pediatrics' examination selecting subspecialty career areas (American Board of Pediatrics)*

| Year | Percentage |
|---|---|
| 1990 | 33 |
| 1995 | 27 |
| 1998 | 20 |
| 2000 | 23 |
| 2004 | 25 |

## NEW STRATEGIES

Despite the great success of these programs and of other related efforts, new strategies are needed to increase the number of pediatric scientists.

In 1999, Dr. Leon Rosenberg wrote, "The human pipeline of physician-scientists is emptying at the worst possible spot – the young end." (2) In 2003, Dr. James Stockman noted, "The seed that leads to the development of a scholarly career is cultivated in soil that begins long before the start of residency." (5) We heed Dr. Rosenberg's and Dr. Stockman's observations and pause to consider priming the pipeline at the "young end . . . beginning [long] before the start of residency."

Many of our current efforts have been directed at the "older end" — medical students, residents, and fellows. These efforts are laudable and some are highly successful (6). We would propose, however, these interventions are not nearly enough and in some instances, may be too late in the young person's development, as Drs. Rosenberg and Stockman suggest. As pediatricians, how do we define the "young end" of the pipeline? We define the "young end" of the pipeline for this presentation as junior high and high school students.

Emerging data about child/adolescent biologic and behavioral development indicate that adolescents may be able biologically and behaviorally to understand scientific principles, and further, they may be excited by science. Educational experiences during one's adolescence often become life-long interests. We recognize that the stage/age of adolescence is a long way from the stage/age of becoming a funded investigator; we acknowledge further that strategies directed toward adolescents would only increase the pool of pediatric scientists in a limited way.

Supporting our thesis that adolescents' brains are "primed" to embrace and to understand science, we first cite data about the physical changes in the adolescent brain from recent brain imaging data. The effects of other biologic factors on the brain during adolescence (genetic, pubertal, and neurotransmitter/receptor changes) is beyond the scope of this presentation (7,8). Then, we shall discuss selected aspects of adolescent behavior as positive attributes for the study of science (9). Last, we shall consider interventions at the "young end of the pipeline" to interest adolescents in science while their brains and behavior are developing.

## ADOLESCENT BRAIN DEVELOPMENT

Both gross anatomic study of children's and adolescents' brains and new quantitative Magnetic Resonance Imaging (MRI) indicate that 90% of adult growth of the brain is completed by six years of age; that is, the size of children's brains do not increase much beyond approximately five to six years of age (10,11). As observers of adolescent development, we recognized many years ago, that there was a major discrepancy between this stated "lack of physical growth" of the brain and of our clinical observations of the development of the highest level of cognitive thinking during adolescence. This discrepancy was a reflection of our inability, until recently, to measure brain function. Now, using quantitative MRI and Computerized Axial Tomography (CAT) scanning, there are data regarding the functional changes in the late childhood and adolescent brain.

The brain, similar to the majority of other organs in the body, changes dramatically during adolescence (10,11). We are learning that there is a host of processes occurring during adolescence, such as regression of certain regions and the development or progression of others that may render the adolescent brain plastic. Indeed, there may be "critical" periods during adolescence when experiences encountered, or conversely, experiences avoided, play a significant role in future interests and long-term pursuits.

In this discussion, we shall consider the development of the two most basic components of brain biology: white matter and gray matter as illustrations of the dynamism of the adolescent brain. We realize that this summary may oversimplify a host of many functional changes occurring at precise levels of brain anatomy, some of which are yet to be defined.

White matter is made up of myelinated axons. Much like insulating an electrical wire, myelination of neurons leads to faster, more efficient neurotransmission (10,11). The total volume of white matter in the brain increases linearly with age throughout childhood and adolescence (Fig. 1), likely secondary to an increase in both axon diameter and myelin sheath thickness (10–13). There are minor differences in the slope of increase in white matter in the four major lobes (frontal, parietal, temporal, and occipital) (10).

The corpus callosum consists of myelinated axons and is the main connection between similar parts of the right and left hemispheres of the brain (10,11). Fig. 2 illustrates the yearly increase in the area of the corpus collosum per year from MRI studies for subjects between 16 and 45 y of age. The rate of

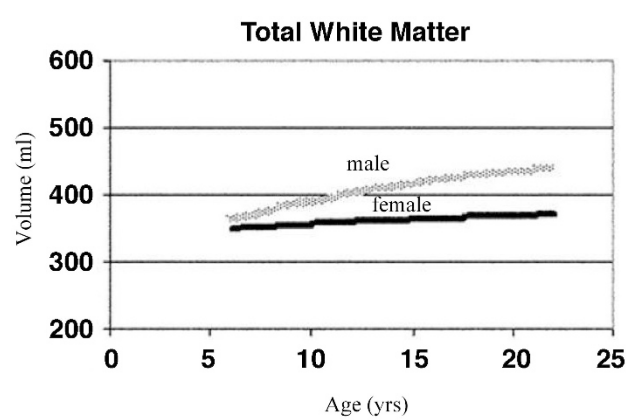


**Figure 1.** Total White Matter. Reprinted from Giedd JN, Ann NY Acad Sci 1021:77–85, ©2004 New York Academy of Sciences, with permission.

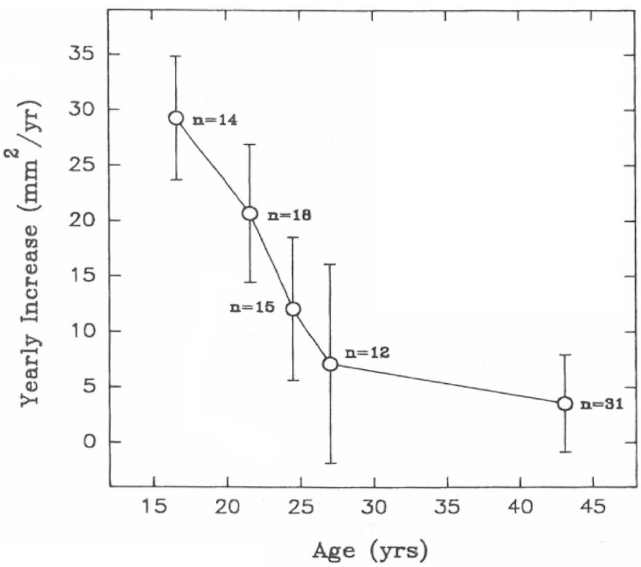


**Figure 2.** Yearly Increase In The Corpus Callosum Area. Reprinted from Giedd JN, et al. Nat Neurosci 2:861–863, ©1990 American Neurologic Association, with permission of John Wiley & Sons, Inc.

increase in the area of the corpus callosum is greater between 16–27 y of age than it is from 28 to the mid-40s (14). This increase in the area of the corpus callosum may maximize the efficiency of transmission of signals at adolescence and young adulthood, thus enhancing learning. Unlike the other areas of white matter, the anterior segment of the corpus callosum matures earliest, while the posterior region matures later (11). This late maturation of higher level processing is consistent with the development of formal operational thinking during adolescence, suggesting that adolescence may be the time when maximal speed and effectiveness of cognitive processing and skills are attained.

Cortical gray matter makes up the surface of the brain and consists of neurons surrounded by supporting cells. Compared with the increases in volume in white matter with increasing age in children and adolescents, there is a preadolescent increase and then, an adolescent/post-adolescent decrease in volume in cortical gray matter. (Fig. 3) (10,11,15,16) There is greater regional variation than in white matter (10).

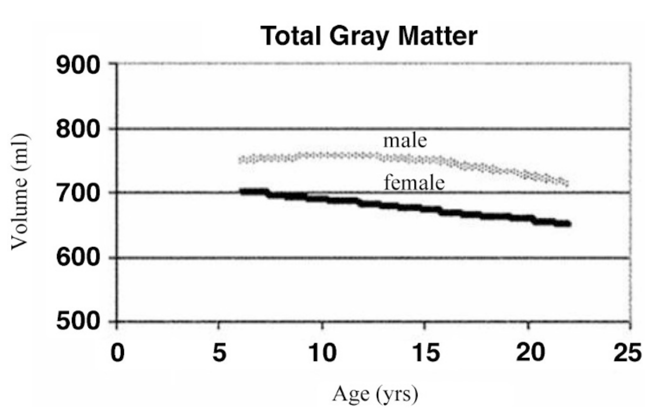


**Figure 3.** Total Gray Matter. Reprinted from Giedd JN, Ann NY Acad Sci 1021:77–85, ©2004 New York Academy of Sciences, with permission.

In a large-scale longitudinal study, investigators performed MRI scans on the brains of 145 healthy children and adolescents at two-year intervals, and suggested a second wave of synapse overproduction. They reported that while growth/pruning cycles occurred in different functional areas of the brain at different times in development, there was a significant increase in gray matter volume in the frontal lobe in late childhood—the areas associated with planning, organization, judgment, and regulation of emotion—peaking at about age 11 in girls and 12.1 y in boys, roughly the same timing as puberty (10,13). This increase was followed by a post-adolescent decrease in gray matter volume. Parietal-lobe gray matter and temporal-lobe gray matter showed similar patterns of preadolescent increase and post-adolescent decrease of volume, with variation in slopes for different areas of the brain and changes varying by age. Pre- and post-adolescent slopes were greater for parietal than for frontal lobes.

On the basis of this review of the data, we believe that there is increasing evidence that adolescence is a time of immense possibilities and vulnerabilities of the adolescent brain as well as being a critical period for training the developing brain for science; that is to wire the brain through early exposure to challenging scientific, intellectual experiences.

In an interview, Dr. Jay Giedd at the National Institutes of Health used the example that if a teen is participating in sports, or music, or academics, the cells and connections associated with these activities will be hard-wired, whereas a teen lying in front of the television or playing video games might develop neuronal connections that promote those activities (17). With maturation of the frontal lobes, increased myelination leading to increased speed and effectiveness of cognitive and higher associative processes, the adolescent period is one of enormous potential for brain development and training. As such, this dynamic period of growth and maturation certainly offers opportunities for the introduction of science. However, a dynamic functional brain only is part of the story of encouraging scientific interest among adolescents. As any clinician or parent of a teenager can attest, adolescence is, also, a time of increased cognitive capability, risk-taking, and novelty-seeking. To interest our young in science, we must also capture these overwhelmingly influential facets of their development.

## ADOLESCENT BEHAVIOR

We shall cite briefly only three domains of adolescent behavior for this discussion. These three areas are: cognitive development, novelty-seeking/risk-taking, and social (peer) interactions.

During adolescence, most teenagers experience remarkable cognitive development. Their ultimate cognitive capacity depends upon their genetic potential and environmental experiences. Most maturing teenagers develop abstract thinking, that is, formal operational thinking, or the ability to think about thoughts and the ability to reason. These remarkable changes in adolescent cognitive development provide opportunities to engage young persons in challenging intellectual activities to reinforce their new competencies (18).

At the same time adolescents develop formal operational thinking, they engage in novelty-seeking/risk-taking behaviors. Some of this novelty-seeking results from their sophisticated cognitive capacity. Further, they may seek the "high" that accompanies taking a risk (19). The origins of these behaviors are most likely influenced by both the changes in brain structure and brain function as well as by changes in the environment. Others believe that ". . . increased risk-taking and an altered response to novelty can be beneficial in learning new strategies for survival independent of the parents." (20, p28). We perceive that opportunities for studying science provides sanctioned novelty-seeking and risk-taking!

Social (peer) interactions are the hallmark of adolescent behavior. Seen throughout the primate kingdom, this behavior is believed to shape the adolescents' emerging independence from the family of origin. The peer group provides a setting for novelty-seeking, shared experiences, and learning. These very interactions, also, encourage the pursuit of common interests among peers (science clubs, teams, etc.) Thus, we might conclude that teaching science to groups of adolescents might build upon increased cognitive ability, novelty-seeking, and peer interactions.

## INTERVENTION AT THE "YOUNG END"

Based upon our understanding of adolescent development, our commitment to science, and our responsibility to train the young scientifically, faculty members of departments of pediatrics might reach out to the junior high and high schools in our communities and consider attracting, as Dr. Rosenberg described, "the young end" of the pipeline for pediatric scientific careers. It is never too early.

Examples of community, institutional partnerships, for which there are formal evaluations in the literature are: the Massachusetts General Hospital//Timilty Partnership (Science Fair Mentoring Program); Hampshire College programs (Summer Science Exploration Program); and the University of Rochester program (Summer Science Academy) (21–24). The latter will be used as an illustration of programs emanating from a medical school directed toward pre-college students.

The Rochester program is located in the Department of Environmental Medicine at the University of Rochester; the program has considerable federal funding (23,24). The University of Rochester Summer Science Academy (SSA) is a popular 2-4 wk course for high school students during the summer. There have been 20 to 39 students annually since 1996. Two to four Rochester-area high school science teachers participate as laboratory instructors or assistants during each summer along side medical school faculty.

**Table 2.** *SSA curriculum*

| Curriculum options |
|---|
| Laboratory experimentation |
| Bioethics discussion |
| Computer workshops |
| Library research |
| Field trips |
| Use of state-of-the-art equipment not available in high school |

The curriculum is noted in Table 2. Each student completes a research project and presents the data to faculty and parents.

The long-term follow-up (1–7 y) of participants in this program based on qualitative data are promising. For example, direct quotes from the graduates are as follows: "I was. . . dead-set in pursuing. . .biology. . .look back on the experience as a milestone." ". . .cemented my interest in microbiology, will pursue MD/PhD program." "SSA contributed to my interest in science. . .will be applying to medical school." (23,24) Ideally, in the future, in the spirit of this presentation, it would be interesting to query whether before/after functional MRI scanning might identify any changes in the adolescents' brains following the SSA experience.

## CONCLUSIONS

We must be committed to increasing the number of young people entering scientific careers; simply stated we need more pediatric scientists. The exact means to achieve this goal are unclear and multiple approaches may be necessary. Starting our efforts "earlier in the pipeline" may enhance the number of young people who then commit their careers to pediatric science.

Many solutions to national problems are local. The success of the PSDP indicates that targeted, thoughtful programs, locally excellent and nationally conceptualized, created by our academic pediatric leadership, can have a very positive and long-lasting effect on children's health and on pediatric science. Simply introducing science to students at a summer science camp may not have the desired effect of producing pediatric scientists many years later.

Rather, we raise the question as to how to increase the number of pediatric scientists as a means to challenge ourselves to seek innovative solutions. In addition, it is a way for us to apply our knowledge of adolescent development and our joy of working with children/adolescents as a means to achieve the greater goal of producing more pediatric scientists.

Adolescents are biologically and behaviorally primed to participate in high-level sophisticated scientific experiences. The plasticity of the adolescent brain and potential "critical" periods for exposure to meaningful science education provide the opportunity to "prime the adolescent brain" for science. Motivation-reward and novelty-seeking of adolescents, also, provide another developmental opportunity to capitalize on their energies. As developmental specialists eager to attract the next generations to pediatric science, we as pediatricians should be leading university-community partnerships to fill the pipeline for pediatric scientists earlier rather than later.

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## Errata

In the article, "Plasminogen Activator Inhibitor-1 and Tissue-Plasminogen Activator in Minority Adolescents with Type 2 Diabetes and Obesity," by Vatcharapan Umpaichitra, et al., *Pediatric Research* 2005: 58:483–487, the following changes were not made to the article. The editors regret the error.

1. Author affiliations should read:
Department of Pediatrics [V.U.], The Brookdale University Hospital and Medical Center, Brooklyn, NY 11212; Department of Anatomy and Cell Biology [M.M.H.], Department of Pediatrics [S.C.], State University of New York Health Science Center at Brooklyn (SUNY Downstate), Brooklyn, NY 11203

2. In the Abstract, the sentence beginning "PAI-1 activities were significantly . . ." should read: PAI-1 activities were significantly greater in patients than in control subjects [fasting, $23.4 \pm 2.6$ *versus* $12.9 \pm 2.0$ U/mL ($p < 0.004$); AUC, $101.7 \pm 12.1$ *versus* $57.6 \pm 6.5$ $U \cdot h \cdot mL^{-1}$ ($p < 0.003$)].

3. In the section "Fat-loading tests and measurements," the line beginning "(0.05 vol or 20% . . ." should read: (0.05 vol or 20% acetic acid:1 vol of plasma) to acidify the plasma.

In the same section, the sentence beginning "Immunologic marker determinations" should read: Immunologic marker determinations (glutamic acid decarboxylase antibodies, islet cell autoantibodies, and insulin autoantibodies) were determined by RIA in the patients with diabetes and were all negative.

4. In the section "Postprandial state," the sentence beginning Total cholesterol, . . . should read: Total cholesterol, HDL cholesterol, and LDL cholesterol AUCs did not differ between the two groups [$28.5 \pm 2.1$ *versus* $25.9 \pm 1.2$ $mmol \cdot h \cdot L^{-1}$ ($p$ = NS); $6.0 \pm 0.3$ *versus* $7.1 \pm 0.4$ $mmol \cdot h \cdot L^{-1}$ ($p$ = NS); $16.9 \pm 2.0$ *versus* $14.8 \pm 1.4$ $mmol \cdot h \cdot L^{-1}$ ($p$ = NS), respectively).

5. In the Figure 1 legend, all of the $h^{-1}$ should be h.

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In the article, "Use of [$^{13}$C]Bicarbonate for Metabolic Studies in Preterm Infants: Intragastric versus Intravenous administration," by Maaike A. Riedijk, et al., *Pediatric Research* 2005; 58:861–864, the equation on page 862 should read:

$$\text{Estimated body } CO_2 \text{ production} = [(\text{IE infusate/IE breath})\text{-}1] \times \text{tracer infusion rate} \times 1000$$

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In the article, "Infants with Intrauterine Growth Restriction Have Impaired Formation of Docosahexaenoic Acid in Early Neonatal Life: A Stable Isotope Study," by Adolfo Llanos, et al., *Pediatric Research* 2005; 58:735–740, an author's name is spelled incorrectly. The correct name is Yuhong Lin.