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A QUESTION OF GENIUS: ARE MEN REALLY SMARTER THAN WOMEN?

> There is perhaps no field aspiring to be scientific where flagrant personal bias, logic martyred in the cause of supporting a prejudice, unfounded assertions and even sentimental rot and drivel have run riot to such an extent as here.
>
> —HELEN THOMPSON WOOLLEY
> Psychologist, 1910

> It would be difficult to find a research area more characterized by shoddy work, overgeneralization, hasty conclusions, and unsupported speculations.
>
> —JULIA SHERMAN
> Psychologist, 1977

JOBS AND EDUCATION—that's what it's really all about. At the crux of the question "Who's smarter, men or women?" lie decisions about how to teach reading and mathematics, about whether boys and girls should attend separate schools, about job and career choices, and, as always, about money—how much employers will have to pay to whom and what salaries employees, both male and female, can command. These issues have formed an unbroken bridge spanning the length of a century. Across that passageway, year in and year out, have trucked thousands upon thousands of pages written to clarify our understanding of the intellectual abilities of men and women. Hundreds of this nation's top educators, biologists, and psychologists have done thousands of studies offering us proofs, counterproofs, confirmations, and refutations. Yet the battle rages with as much heat and as little light as ever.

Today's claims are quite specific. The science feature page of the *Boston Globe* had the following headline in an article on education:

> IS MATH ABILITY AFFECTED BY HORMONES? Far more boys than girls get top scores in math test.[1]

In the same vein a mathematics teacher in a Warwick, Rhode Island, high school writes:

> As a mathematics educator with over 25 years in dealing with female pupils and female mathematics teachers, I do have direct evidence . . mathematics is the water in which all intellectual creativity must mix to survive. Females, by their very nature, are oleaginous creatures in this regard. Or . . . as the song says: "Girls just wanna have fun."[2]

Theories abound that there are more male than female geniuses and that boys wind up ahead of girls in the classroom and hence in the job market. Why? Because, some would hold, hormonal differences between the sexes cause differences in brain structure and function. These in turn lead to differences in cognitive ability. Boys supposedly develop greater visual-spatial acumen; girls develop better verbal and communication skills. Although many researchers take such differences for granted, my own reading of the scientific literature leaves me in grave doubt about their existence. If sex differences in cognition exist at all they are quite small, and the question of their possible origins remains unanswered. Nevertheless, the claim of difference has been and continues to be used to avoid facing up to very real problems in our educational system and has provided a rationale for discrimination against women in the workplace. The issue of cognitive differences between the sexes is not new. Scientists and educators used versions of this particular scientific tale even before the turn of the century.

In 1903 James McKeen Cattell, a professor at Columbia University and editor of *Science*, the official journal of the American Association for the Advancement of Science, noted that among his list of one thousand persons of eminence throughout the ages, only thirty-two were women. Although Cattell expressed some surprise at the dearth of eminent females, he felt that it fit with the fact that in his *American Men of Science* only a tiny number of women

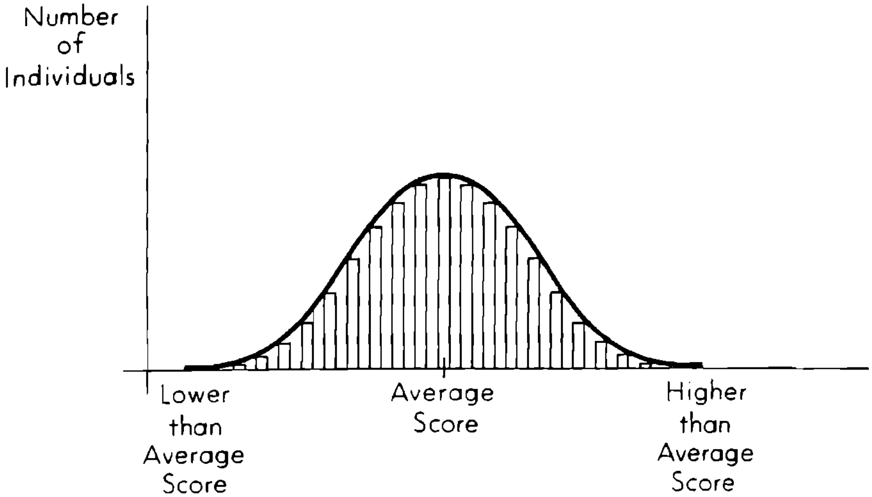

FIGURE 2.1
Genesis of the Bell-shaped Curve

appeared among the top thousand scientists. From his standpoint "there [did] not appear to be any social prejudice against women engaging in scientific work," hence he found it "difficult to avoid the conclusion that there is an innate sexual disqualification."[3] Another Columbia professor, Edward L. Thorndike, an influential educational psychologist and a pioneer in the use of statistics in educational research, also commented on the lack of intellectually gifted women. As an advocate of educational efficiency, he saw little sense in squandering social resources by trying to train so many women to join the intellectual elite. An exceptional female could become an administrator, politician, or scientist, but the vast majority were better off learning to become nurses and teachers where, as he put it, "the average level is essential."[4]

Thorndike and Cattell both thought that biological differences between the sexes explained the rarity of extremely intelligent women. Men, it seemed, were by nature more variable and this variability created more male geniuses. Since the line of reasoning may at first seem tortured, a word of explanation is in order. Researchers give tests to groups of individuals. If one displays the number of people with a particular test score on a graph, as shown in figure 2.1, the distribution of performances usually approximates a bell-shaped curve. The highest part of the curve, showing the scores most frequently attained, represents the average performance.

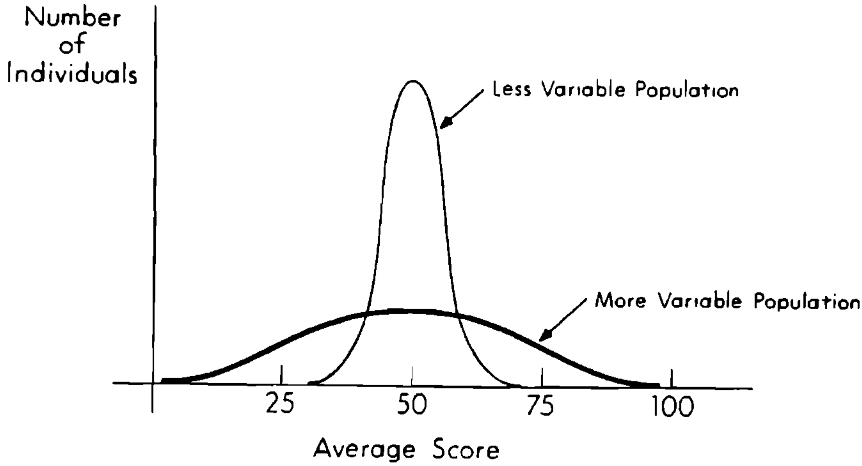

FIGURE 2.2
Bell-shaped Curves of Populations with the Same Average Trait but with Different Degrees of Variability

Individuals whose scores fall to the right have performed above average while those whose scores fall to the left were below average.

There is, however, more than one way to reach an average. On a test in which the highest possible score is 100, for example, the average might be 50. If the average resulted from the fact that everyone scored very close to 50, the bell-shaped curve would be very tall and narrow. If, on the other hand, the average score of 50 resulted from a population of individuals, some of whom scored in the 90s and some of whom scored in the teens, the shape of the bell would be low and squat (see figure 2.2). In the former example, where all of the individual scores hover right around the group average, the *standard deviation from the mean* is small, while in the latter case it is quite large. A population with a large standard deviation is, quite obviously, highly variable, making it harder to predict the performance of any one individual in the group.

What does all this have to do with an excess of male geniuses? Thorndike and others agreed that men and women had the same *average* level intelligence. But men were more variable; thus, their intelligence curve looked more like the short, squat one drawn in figure 2.2, while the women's looked more like the tall, narrow one. (I've exaggerated the effect to illustrate the point more clearly.) What counted for the men was the above-average tail on the bell curve, containing as it must individuals who surpassed the abilities of even the most gifted women. (The variability hypothesis also allows for the presence of a greater number of subnormal males, a fact acknowledged by both Thorndike and Cattell.)

The theme of variability is an old one. Before Darwin published his theory of evolution, Western scientists considered variability a liability to the species. They also thought that *women* constituted the more variable sex. Darwin, however, won credence for the ideas that populations with greater variability among individuals had a better chance of withstanding the evolutionary test of time, and that males were more likely to vary than were females. Thus, when high variability was considered to be a biological drawback, it was attributed to the female of the species; in its post-Darwinian status as a biological benefit, it became a male property and males remained the progressive element, the active experimenters of their race. In return for relinquishing their variability, women received the mantle of conservation, becoming the passive vessels of racial purity.[5]

A number of psychologists working in the first quarter of the twentieth century published competent scientific studies disputing the claim that men were more variable than women.[6] But the ideas of Thorndike and others that women should be educated for professions such as nursing, social work, and teaching were backed by powerful social forces. Cattell, for example, wrote at a time when women had begun to outnumber men as students in many of the large state universities—California, Iowa, Minnesota, and Texas among them.[7] The "problem of feminization" concerned educators deeply. While administrators at the University of Chicago contained the large growth in women students by placing them in a separate college within the school, other institutions responded by urging women to enter special all-female fields. Home economics, for one, provided a new place for the increased number of women chemists.[8] The structure of the work force had also changed markedly. With job segregation a fact of life for women,[9] Thorndike and others encouraged the massing of women into certain (low-paying) occupations by urging the utility of separate vocational education for males and females. Federal aid for industrial arts programs for boys and home economics courses for girls supported this process. According to one analysis, "Hospital and school administrators welcomed these programs as a solution to their growing need for competent but inexpensive workers. Businessmen supported the growing number of secretarial and commercial courses for women for similar reasons."[10] The biological views of Cattell and Thorndike were so congenial to the economic and political establishment of the period that rational, scientific challenges to their work were studiously ignored.[11]

The debate over variability went on into the 1930s, when it finally seemed to have been laid to rest by Lewis Terman, an expert on mental testing.[12] But, like the phoenix arising fresh and beautiful from the ashes of its own cremation, the theory of variability has appeared once more on the modern scene. Curiously, its rebirth brings out few new facts, presenting only a somewhat modernized formulation of the same old idea. In 1972 the *American Journal of Mental Deficiency* published an article by Dr. Robert Lehrke entitled "A Theory of X-linkage of Major Intellectual Traits."[13] The editors were sensitive to the fact that the article would provoke controversy and took the somewhat unusual step of inviting three well-known psychologists to write critiques, which followed the original article along with a round of response from Lehrke.[14] Lehrke noted that there were more institutionalized mentally retarded males than females, an observation made by many but poorly understood.[15] Is it possible that parents keep retarded girls at home more often? Are boys more susceptible to environmental shock? Or, does the X-linkage of certain metabolic diseases* make boys more likely to be institutionalized? Lehrke's hypothesis holds that a number of genes relating to intellectual ability reside on the X-chromosome and that because of the peculiarities of chromosomal inheritance, X-linkage means that males will exhibit greater variability in intelligence. Although he begins with the supposed excess of mental defectives Lehrke does not shrink from the implication that there would also be more genius-level males. As he rather succinctly wrote: "It is highly probable that basic genetic factors rather than male chauvinism account for at least some of the difference in the numbers of males and females occupying positions requiring the highest levels of intellectual ability."[16]

To understand some of the details of Lehrke's argument it is worthwhile to review the idea of X-linkage. Males and females differ genetically. In addition to twenty-two pairs of chromosomes called autosomes, females have two X chromosomes. Males, on the other hand, supplement their twenty-two autosomes with one X and one Y chromosome. Because X and Y chromosomes are associated with the development of gender, they are sometimes referred to a

* Hemophilia, for example, is X-linked and therefore affects boys more frequently than girls.

the sex chromosomes. Hemophilia, a particularly famous X-linked disease, illustrates the process of X-linked inheritance. The hemophilia gene, which resides on the X chromosome, exists in two states—normal and mutant. The normal gene codes for a factor that helps blood to clot, while the mutant gene cannot aid in the production of the clotting factor. Since males carry only one X chromosome, and since the Y chromosome cannot counteract the effect of genes on the X chromosome, a male will suffer from hemophilia if he carries an X chromosome with the mutant state of the gene. A female must carry two abnormal X chromosomes in order to be a bleeder, because she will be protected as long as one X chromosome carries the normal gene.

Children, however, can inherit the mother's abnormal X chromosome. Since sons derive their X chromosomes from their mothers, a mother carrying the hemophilia factor on one of her X chromosomes stands a 50 percent chance of having a hemophiliac son. On the other hand, since daughters receive one X chromosome from the mother and the other from the father, a stricken girl must have a hemophiliac father in addition to a carrier mother. In other words, if hemophilia runs in the family, sons will express the trait more frequently than will daughters.

Lehrke hypothesizes that, unlike the clotting factor gene that exists in one of two possible states, an X-linked gene for intelligence might exist in as many as six graded states—called *alleles* in the terminology of geneticists—running from lower to higher intelligence. A female would always carry two of these (one on each X chromosome), and the one evoking greater intelligence might then compromise with the one for lesser intelligence. Males, on the other hand, would only carry one allele at a time. If that one allele coded for a low state of intelligence, then the male would express that trait, while if the allele were one for the highest state, the individual would be extremely intelligent. According to Lehrke, then, one would find equal levels of retardation or genius among males and females. However, because expression of extremes of intelligence in females would require two chromosomes with the same very low or very high state of brightness, while expression in males would require the presence of only one, a larger number of males than of females would be found who were either extremely dull or incredibly brilliant. Hence, the greater male variability in intelligence.[17]

The most fundamental assumption in Lehrke's hypothesis is that intelligence is an inherited trait coded for by some finite number of factors called "intelligence genes." This claim has evoke(great controversy, and many well-known biologists have argue(convincingly that (1) it is impossible to define intelligence, and (2 we have no means at our disposal to measure its genetic componen separately from its environmental determinants.[18] Lehrke bolster his argument by citing the work of Arthur Jensen, who figure heavily in a long-standing debate over whether blacks are les intelligent than whites. Jensen and others believe that whites ar smarter and that educational enrichment programs for underprivi leged children are a waste of government money. From his comment about the lower intelligence of slum dwellers, one would suspec that Lehrke agrees with this concept.[19] Lehrke also claims that th existence of several X-linked traits that cause mental retardatio: proves the inherited nature of intelligence. This argument include the hidden, circular assumption that mental deficiency results fror genes specific to the development of intelligence. My point can b illustrated by looking at one often cited example, the disease calle phenylketonuria (PKU).

In the very recent primary literature the simple autosoma inheritance of PKU has been called into question,[20] but virtually a. genetic and medical textbooks use this disease as an example of th straightforward inheritance of a gene that "causes" mental retarda tion. Children born with PKU lack an enzyme called phenyl alanin hydroxylase, which converts the amino acid phenyl alanine—one c the building blocks of large protein molecules—to another amin acid, called tyrosine. Because their cells cannot make this conversior PKU patients accumulate toxic levels of phenyl alanine—from fort to fifty times the normal amount—in the blood and brain. Sinc the brain continues to develop actively even after birth, its cel! may be particularly sensitive to this poison. Indeed, children wit PKU fed on a diet lacking in phenyl alanine develop fairly normall)

The question is whether the existence of the inherited diseas phenylketonuria (or similar diseases of metabolism) provides ev dence that genes govern intelligence. That normal intelligence r(quires normal brain development is obvious, but the existence c PKU says nothing about the presence of genes for intelligence c learning. It merely says that when the entire brain is poisone during a critical period of development, the effects can be disastrou From the point of view of explaining the relationship between gene and intelligence, this is no more informative than asserting, afte smashing someone's head with a sledgehammer, that violence dor to a person's skull causes subsequent mental dullness. The same point can be made for all of the gene and chromosome defects that severely affect normal human development. They give us a glimpse of what can go wrong, but they tell us absolutely nothing—at least in terms of intelligence—about how things work right.

Arguments against the idea of intelligence genes seem sufficient to warrant dismissal of Lehrke's hypothesis.[21] But he both resurrects old data and cites newer information purporting to show once again that males perform more variably on intelligence tests than do females, and those citations merit consideration. Investigating variability in IQ turns out to be a rather formidable task. In one recent study researchers looked for scientifically gifted children by holding math and science contests. They found a greater number of precocious boys than girls, and their top winners were all male. They noted, however, that among the precocious students the boys owned more books and equipment related to math and science, while some of the girls' parents were so uninterested in their daughters' precocity that they didn't even plan to send them to college.[22] The existence of such social differences between the boys and the girls makes the results difficult to interpret. Furthermore, a "talent search" approach looks only at a select group of students who either volunteered for the contests or were recruited by teachers or parents. Although Lehrke doesn't cite this study, he does cite an older one[23] which is subject to the same sorts of uncertainty.

The only way to get some sense of the variability of the population as a whole is to do large-scale, nonselective studies. These are expensive and difficult to design—there is only one well-done research project of this kind in the literature. Lehrke cites this project, a survey of Scottish schoolchildren, to support his view that males vary more than do females. Since the sample was very large, and since sample size is one of the components statisticians use to decide whether a particular difference is significant rather than just random, the small differences in standard deviation found among these Scottish boys and girls turned out to be statistically significant. As one of the respondents to Lehrke's 1972 paper points out, however, the male variability resulted mostly from an excess of males with very *low* scores—a result, perhaps, of physical handicaps that might have interfered with their performance on the timed tests.[24]

Lehrke's response to his critics is maddening. He concedes that "each one of the arguments for X-linkage of major intellectual traits can be interpreted to produce different emphases," but thinks that his emphasis merits attention because it is a simpler explanation.[25] In addition to this weak attempt at scientific rebuttal, and despite the fact that some of his critics are male,[26] Lehrke also directly points to what he thinks is the real source of his trouble:

> Determinants of which viewpoint a person accepts are undoubtedly highly complex, but a single, very simple one is obvious. In the small sample cited, all those accepting the hypothesis of greater male variability have been males, all those rejecting it, females.[27]

In contrast to his assessment of his female critics, however, Lehrke believes himself to be a dispassionate observer:

> I do not feel that I must apologize for the fact that certain implications of the theory may seem . . . to be derogatory to women. Like Topsy, the theory "just growed," its nature being determined by the data. I could not, with scientific objectivity, have changed the final result.[28]

Here, then, we have the elements of a response that will show up again and again in debates touched upon throughout this book. In each case, the proponents of biological explanations of behavior label their attackers as biased, members of some special interest group (women, feminists, Marxists), while choosing for themselves the role of the objective, dispassionate scientist.

Before judging Lehrke's detachment, though, the reader ought to know a little something about the company he keeps. His last article, "Sex Linkage: A Biological Basis for Greater Variability in Intelligence," was published in 1978 in a book entitled *Human Variation: The Biopsychology of Age, Race, and Sex.*[29] The book is dedicated to the memory of Sir Francis Galton, founder of the eugenics movement, while its headquote comes from none other than E. L. Thorndike. Just as interesting, the volume in question is edited by Dr. R. Travis Osborn, a leader in the new eugenics movement,[30] who has received, over the years, financial support from a "philanthropic" organization called the Pioneer Fund, which promotes theories of black inferiority and has supported the work of Drs. William Shockley and Arthur Jensen. (Past members and directors include Senator James O. Eastland, the segregationist senator from Mississippi, and Representative Francis E. Walter, who chaired the House Committee on Un-American Activities during the anticommunist campaigns of the 1940s and 1950s.[31]) Are Lehrke, Osborne, and Jensen (who also has an article in the book) strange bedfellows or, as I suspect, appropriate company—each being a scientist who disclaims responsibility for the social implications of his "objective" facts?

Cattell and Thorndike formed part of the mainstream of educational psychology which to this day carries along such adherents as Lehrke. There were others in the mainstream who rejected the variability hypothesis but argued instead that innate differences between males and females are important when considering what jobs to train for and how to teach—even at the elementary level—such subjects as reading and writing. Among the most widely quoted compilations of data on sex differences is one published in 1968 by Garai and Scheinfeld. In the introduction to their book-length literature review they explicitly state that their purpose is "to make the participation of women in the labor force as efficient as their potential permits." To summarize Garai and Scheinfeld's findings in their own words:

> Females, on the average, surpass males in verbal fluency, correct language usage, spelling, manual dexterity, clerical skills, and rote memory. Males, on the average, are superior to females in verbal comprehension and verbal reasoning, mathematical reasoning, spatial perception, speed and accuracy of reaction to visual and auditory stimulation, mechanical aptitude, and problem-solving ability. *These sex differences foreshadow the different occupational goals of men and women.*[32] [Emphasis added]

In a conclusion echoed in more recent writings by other psychologists, Garai and Scheinfeld infer that women's work preferences lie in the fine arts, literature, social services, secretarial jobs, and assembly-line work because these areas suit their particular aptitudes. Men, in contrast, seem drawn by their special skills to the sciences, mathematics, engineering, mechanics, and construction.

Garai and Scheinfeld call for certain educational reforms to accommodate their findings. They believe that boys are handicapped by coeducational classes because they mature more slowly, while girls are distracted, especially in more difficult subjects, by their need for approval and interaction with others. Their solution would be a return to single-sex classes, at least in high school. Garai and Scheinfeld also suggest that there are separate feminine and masculine ways of learning subjects such as mathematics and reading, and that teaching methods for these subjects ought to be reevaluated. This thought, too, remains current. In a research paper appearing in

Science magazine in 1976,[33] psychologist Sandra Witelson concludes that boys' and girls' brains have different physical organizations and that current methods of teaching reading (which stress phonetics rather than visual memory) may favor girls while handicapping boys. In an interview she, too, said that "separate groups or classes for the sexes would be beneficial for teaching reading."[34]

In this day of increasing coeducation, the thought of resegregating classrooms by sex carries a certain irony. At the college level there *is* evidence that coeducation as currently practiced may harm *female* students.[35] But is the solution to return to a separate but unequal form of education,[36] or to identify and remedy whatever it is about coeducation that functions to discourage female students? Of course if one believes in innate sex differences, then the latter makes no sense.

With echoes of James McKeen Cattell in our ears, we find ourselves once again in a period in which females outnumber males on the college campuses. In the current political climate the enrollment changes have led not to a move to cordon off the females as in Cattell's day, but instead to a call from students for more female faculty and better role models. Garai and Scheinfeld, however, call for the "defeminization of the elementary classroom."[37] There are, they feel, too many women teachers whose emphasis on conformity and good behavior stifles the creative expression of little boys; girls, too, need more male teachers, especially if they are to be encouraged (at least the more talented ones) to study science or to improve their creative abilities. Garai and Scheinfeld claim that "almost exclusive staffing of libraries with women and of schools with women teachers create[s] a climate which confronts the boy with hostility and lack of understanding," curiously echoing a diatribe written by Cattell in 1909 in which he, too, deplored the dominance of the female "school principal, narrow and arbitrary, and the spinster, devitalized and unsexed" over the school lives of little boys and girls.[38] Thus, while feminists call for more female role models, some psychologists call for a return to the male-dominated classroom. Is there truly no scientific evidence to tell us who is right?

TABLE 2.1
Summary of Maccoby and Jacklin's Findings on Sex Differences

Unfounded Beliefs About Sex Differences	*Open Questions of Difference*	*Fairly Well Established Sex Differences*
Girls are more social than boys	Tactile sensitivity	Girls have greater verbal ability
Girls are more suggestible than boys	Fear, timidity, and anxiety	Boys excel in visual-spatial ability
Girls have lower self-esteem than boys	Activity level	Boys excel in mathematical ability
Girls are better at rote learning and simple repetitive tasks; boys are better at higher level cognitive processing	Competitiveness	Boys are more aggressive
Boys are more analytic than girls	Dominance	
Girls are more affected by heredity; boys are more affected by environment	Compliance	
Girls lack achievement motivation	Nurturance and "maternal" behavior	
Girls are more inclined toward the auditory; boys are more inclined toward the visual		

SOURCE: Eleanor Maccoby and Carol Nagy Jacklin, *The Psychology of Sex Differences* (Stanford, Calif.: Stanford University Press, 1974).

Male Skills/Female Skills: The Elusive Difference

The best starting point for discussing the difference between male and female skills is a book published in 1974 by two psychologists, Eleanor Maccoby and Carol Nagy Jacklin.[39] They summarize and critically evaluate a large body of work on the psychology of sex differences, concluding that at least eight different claims for sex differences (see left-hand column in table 2.1) were *disproved* by the results of then available scientific studies and that the findings about seven other alleged differences (see middle column) were either too skimpy or too ambiguous to warrant any conclusions at all, but that sex differences in four areas—verbal ability, visual-spatial ability, mathematical ability, and aggressive behavior—were "fairly well established" (see right-hand column). We turn our attention for the remainder of this chapter to the first three of these differences: verbal, visual-spatial, and mathematical abilities. The fourth, aggressiveness, we will consider in chapter 5.

Verbal Ability

Many people believe that little girls begin to talk sooner than do little boys and that their greater speaking abilities make girls better able to cope with the word-centered system of primary education. Maccoby and Jacklin cite one summary of studies done before 1950 that points to a trend of earlier vocalization in girls. The gender differences, however, are small and often statistically insignificant, and, in fact, many of the studies show no sex-related differences at all. In their review of the literature subsequent to 1950, Maccoby and Jacklin remain skeptical about the existence of sex differences in vocalization for very young children. Although a small body of more recent work suggests that there probably *is* something to the idea that girls talk sooner than boys,[40] my own assessment is that the differences, if any, are so small relative to the variation among members of the same sex that it is almost impossible to demonstrate them in any consistent or statistically acceptable fashion.

The studies on early vocalization raise several interrelated issues in basic statistics that must be understood in order to delve further into the controversies surrounding verbal and spatial abilities. Among these issues are statistical significance and its relationship to sample size and the size of differences *between the sexes* compared with the size of differences *between any two individuals* of the same sex. This latter issue, of which psychologists in the field of cognitive differences have become increasingly aware, places the importance of sex differences in a whole new light.

One widely accepted scientific procedure for comparing averages obtained from individual measurements of members of a population is to apply a statistical test to the information gathered. An average difference between two groups could occur by chance and therefore would reflect no real distinction between the two test populations.

A random difference is particularly likely if the individual trait under study in one or both of the groups varies a lot (that is, has a large standard deviation). Scientists have devised several methods for examining experimental information to find out if average differences are real rather than chance. Most such statistical tests look at two things—the variability of the populations under comparison and the size of the test sample. If a test sample is very small, very variable, or both, the possibility that found differences are due to chance is great.

Suppose, for example, I suspect that more males than females have blue eyes. In order to test my idea, I look at three groups of ten students (five men and five women) borrowed from three different classrooms. In the first group it turns out that two-thirds of the men but only one-third of the women have blue eyes, in the second that two-thirds of the women but only one-third of men have blue eyes, while in the third classroom all five of the men have blue eyes, but none of the women do. Taking the average of my three samples, I see that, overall, 66 percent of the men have blue eyes compared to only 33 percent of the women.

In standard scientific convention one tries to discover the probability that a particular result can occur by accident. Because my sample in the preceding example was small and variable, this probability was 65.6 percent (calculated using a special statistical test that takes into account variance and sample size). Scientists use an agreed-upon albeit arbitrary limit, whereby a hypothesis is rejected if the probability of a found difference occurring by chance exceeds 5 percent. Thus I must reject the hypothesis that more boys than girls have blue eyes, as it is based on a poor data sample. If the probability of a difference existing by chance is 5 percent or less, then one accepts the hypothesis and calls the results *statistically significant.*

Statistical significance, however, can mislead, because its calculation comes in part from the size of the measured sample. For example, in order to show that two groups differ in performance by four IQ points, one must use a sample size of about four hundred in each test group (that is, if the sexes were compared, four hundred boys and four hundred girls). Greater differences in IQ can be shown with smaller groups, while *extremely large* samples may reveal statistically significant results, according to the convention of 5 percent probability, even though they are intellectually meaningless. Thus, in a sample of 100,000 males and 100,000 females,

TABLE 2.2
Sex-related Cognitive Differences: Verbal Reasoning in Subjects over Age Sixteen

Variable	*Number of Results*	*Female Superior*	*Male Superior*	*No Difference*
Oetzel (1966)				
Vocabulary	4	2	0	2
Verbal Problem Solving	1	1	0	0
General Verbal Skill	4	1	0	3
Abstract Reasoning	4	1	1	2
Maccoby and Jacklin (1974)				
Verbal Abilities	25	8	1	16
Droege (1967)	2	2	0	0
TOTAL	40	15	2	23

NOTE: Julia Sherman, *Sex-Related Cognitive Differences: An Essay on Theory and Evidence* (Springfield, Ill.: Charles C Thomas, 1978), 40. Courtesy of Charles C Thomas, Publisher.

an IQ difference of 0.02 points would be highly significant (probability of 0.1 percent). But it doesn't actually matter if one person has an IQ of 100 and another an IQ of 100.02, because the IQ test is not designed to measure such small differences.[41]

Using a somewhat unusual statistical manipulation, Garai and Scheinfeld concluded that girls were poorer at verbal reasoning than were boys. In order to reach that conclusion, they used the following approach. They knew that boys matured physically at a slower rate than did girls. In studies done on children of the same age, then, they believed the girls to be physically more mature and thus not *really* age-matched with the boys. They reasoned, therefore, that any of the studies that showed boys and girls to perform equally actually provided proof of male superiority![42] One way to get around the problem of different maturation ages is to look carefully at the studies done on people over the age of sixteen, a point in the life cycle at which the large majority of both boys and girls have gone through puberty. Dr. Julia Sherman has done just this. Her results, reproduced in table 2.2, show that in forty different studies of verbal reasoning done on subjects over the age of sixteen, females did better in fifteen and males in two, while in twenty-three there were no sex-related differences.

Two observations can be made from this information. First, when there *are* sex-related differences in verbal reasoning, females usually come out ahead. Second, in the majority of cases there are no differences at all. What, then, is the take-home message? Maccoby and Jacklin chose to emphasize the female superiority in the cases where there is some difference. They are, however, perfectly aware that the frequent inability to find any difference could be quite important. Given these data, choosing to believe in sex-related differences in verbal ability is a judgment call about which knowledgeable scientists can very legitimately differ.

More recently several researchers have related the difficulty of showing differences in verbal ability to the small size of any such differences. All the papers reviewed by Maccoby and Jacklin used what is called the *hypothesis-testing approach* to the study of sex differences. Using this approach, a researcher hypothesizes the existence, for instance, of a difference in verbal ability between boys and girls. Tests are given, average scores for boys and for girls are calculated, and the means, the standard deviations, and the number of subjects used to measure the statistical significance of any difference are presented. Maccoby and Jacklin simply tabulated how frequently a particular significant difference showed up in such studies.

Since the publication of their book, however, a new approach known as *meta-analysis* has been used by Jacklin and others to reevaluate their 1974 conclusions.[43] The new approach looks at the *size* of group differences, thereby allowing questions about such matters as verbal ability to be phrased in the following way: "If all you knew about a person was his or her score on a test for verbal ability, how accurately could you guess at his/her sex?" Meta-analysis is a highly sophisticated way of evaluating the meaning of several interrelated studies. It is simple in principle, albeit statistically complex. Instead of calculating separately the averages and standard deviations of males and females, one looks at the entire population (males and females together) and estimates the variability in the population as a whole using a statistic called the *variance*, which is related to the standard deviation.[44] Like the standard deviation, the variance tells one about the appearance of the bell-shaped curve that summarizes individual scores. In meta-analysis, one calculates how much of the variance found in the mixed population can be accounted for on the basis of gender, and how much is due to variation between members of the same sex and/or experimental error. We have already seen with the hypothesis-testing approach how one can obtain a meaningless but statistically significant difference by using a very large sample size. Meta-analysis provides a way of telling how large a given statistical difference is and thus how meaningful it is in reality.

Using meta-analysis, then, what becomes of Maccoby and Jacklin's "well-established sex difference" in verbal ability (see table 2.1)? It teeters on the brink of oblivion. Dr. Janet Hyde, for instance, calculated that gender differences accounted for only about 1 percent of the variance in verbal ability, pointing out that the tiny size of the difference could explain why so many of the studies cited by Maccoby and Jacklin show no difference at all.[45] Two other psychologists, Drs. Robert Plomin and Terry Foch, come to the same conclusion: "If all we know about a child is the child's sex, we know very little about the child's verbal ability."[46] Clearly, it makes little sense to base educational and counseling decisions that relate to verbal ability on simple observation of a child's sex, rather than on some actual analysis of his or her particular capacities.

Visual-Spatial Perception

"Males," one well-known psychologist has said, "are good at maps and mazes and math. . . . Females, by contrast, are sensitive to context."[47] Alliterative, yes, but is it true? Again, Maccoby and Jacklin provide the starting point. As with verbal ability, they conclude, there are no sex-related differences in visual-spatial abilities until adolescence. A summary of their findings from studies done on adolescents and adults appears in table 2.3. Spatial ability turns out to be somewhat elusive, but Maccoby and Jacklin have isolated two types: spatial/visual/nonanalytic and spatial/visual/analytic. Some scientists refer to this latter skill as *field articulation.*

The evidence for sex-related differences in visual-spatial ability seems a little more convincing than that for verbal differences, but the problem of "negative" data appears with both. More than half the time no sex differences show up in the visual/analytic studies, but when they do appear they always favor males. The most consistent differences materialize from the most widely used test, the rod and frame test. In this test the subject sits in a totally dark room in a chair facing a large (forty inches on a side), vertically held, luminescent frame. Bisecting the frame is a lighted rod. In one version the experimenter tilts the frame in various ways and the subject adjusts the rod to the vertical of the room, ignoring the immediate context of the tilted frame. In a different version, the

TABLE 2.3
Spatial Abilities of Adolescents and Adults

Skill	*Number of Studies in which Males Performed Better*	*Number of Studies in which Females Performed Better*	*Number of Studies for which No Difference Was Found*	*Total*
Visual/Nonanalytic[a]	8	0	2	10
Visual/Analytic				
Rod and Frame or Similar Test[b]	7	0	5	12
Embedded/Hidden Figures Test	3	0	6	9
Block Design Tests	2	0	2	4
Percentage for Visual/ Nonanalytic	80%		20%	
Percentage for Visual/ Analytic	48%		52%	

SOURCE: Eleanor Maccoby and Carol Nagy Jacklin, *The Psychology of Sex Differences* (Stanford, Calif.: Stanford University Press, 1974), tables 3.7 and 3.8.
[a] A variety of different tests involving mazes, angle matching, and 2- and 3-D visualization were used. The same test was rarely used twice.
[b] Body attitude test.

subject's chair is tilted, and again he or she must make the rod inside the frame perpendicular to the floor. As seen in table 2.3, Maccoby and Jacklin cite twelve studies using this test. Although women never performed better than men, in five of the twelve cases there were no sex-related differences.

Dr. H. A. Witkin, the psychologist who developed and popularized the rod and frame test, dubbed those who performed them well *field independent* and those who performed them poorly *field dependent*. Field-dependent people, Witkin and his collaborators held, were less able to ignore distracting background information in order to zero in on essentials. They suggested a relationship between general intelligence, analytical ability, conformity, passivity, and visual-spatial abilities. More recently, the fact that field-dependent and field-independent personalities just happen to correlate with male/female stereotypes has led a number of investigators to drop the use of the terms. It is now clear that these two tests, at best, record some aspect of visual skill, but have nothing to do with analytical ability. Witkin himself gave a tactile version of a test designed to measure field dependence to blind men and women and, except for one case favoring females, found no sex-related differences.[48]

Some potential for sex bias is built into the rod and frame test. Picture the following: a pitch dark room, a male experimenter, a female subject. What female would not feel just a little vulnerable in that situation? Although one would expect experimenter-subject interactions to be different for males and females in such a set-up, the studies cited by Maccoby and Jacklin apparently don't take into account this possibility. In one version of the test, the subject must ask the experimenter to adjust the rod by small increments to the position he or she believes to be vertical. A less assertive person might hesitate to insist to the nth degree that the experimenter continue the adjustments. Close might seem good enough. If it is true that females are less assertive than males, then this behavioral difference, rather than differences in visual-spatial acuity, could account for their performances in the rod and frame test. At least one experiment suggests the sex bias of the rod and frame test. When, in a similar test, the rod was replaced by a human figure and the task described as one of empathy, sex-related differences in performance disappeared.[49]

The rod and frame test is probably the most suspect of the measures used to assess male/female differences in spatial visualization, but psychologists use other tools as well to measure such skills. In the embedded figures test, the experimental subject must find a hidden word or design within a larger background that camouflages it. Another measure, the Wechsler Intelligence Scales, is used to assess IQ and comprises two tests, one measuring Verbal IQ and the other measuring Performance IQ. The latter is often taken as an indication of spatial ability, although some psychologists believe it to be inadequate for that purpose.[50] Other tests, some of them components of the standard IQ test, are used to probe the ability to visualize three-dimensional figures in the mind's eye. These include the block design test, the mental rotation test, angle-matching tasks, and maze performance. Psychologists have used all of these tests with rather similar results: many times no sex difference appears but when it does, and if the subjects are in their teens or older, males outperform females. The next question is, of course, by how much?

Maccoby and Jacklin point out that, as with differences in verbal skills, differences in spatial skills are quite small—accounting for no more than 5 percent of the variance. Expressed another way, if one looks at the variation (from lowest to highest performance) of spatial ability in a mixed population of males and females, 5 percent of it at most can be accounted for on the basis of sex. The other 95 percent of the variation is due to individual differences that have nothing to do with being male or female.[51]

Despite the small size of the difference, an advocate of the idea that there are naturally more male than female geniuses would have one strong point to make. If one looks at the entire bell-shaped curve, from worst to best, a small sex difference may be of no practical interest. Suppose, though, one looks only at the upper part of the curve, the portion representing those high-level performers one would expect to become math professors, engineers, and architects. Assume for a moment that in order to become a respected engineer one must have a spatial ability in at least the ninety-fifth percentile of the population. Dr. Hyde calculates that 7.35 percent of males will be above this cutoff in comparison with only 3.22 percent of the females. Put another way, currently available information suggests that the ratio of males with an unusually high level of spatial skills to that of females with the same high level of skills might be 2:1, a much larger difference than one picks up by looking at the entire population.[52] Hyde also points out, though, that in the United States only about 1 percent of all engineers are women. If one *did* believe that the only thing standing in the way of an engineering career for women was their immutable sex-related inferior spatial ability, one would still expect to find women in about one-third of all engineering jobs. In short, the differences between men and women in this respect remain too small to account for the tiny number of women who become professional mathematicians, architects, and engineers.

What Makes a Difference?

Sex differences in spatial visualization *do* sometimes exist, even if they don't amount to much. Thus there is an obligation to look into the causes of measurable difference. Because sex-related differences in verbal or spatial abilities appear most clearly at the time of puberty, some scientists conclude that the hormonal changes associated with physical maturation must affect male and female brain development differently. Others point to the social pressures to conform to appropriate role behavior experienced so intensely by adolescents. As seems so often to be the case, the same observation can support both a hypothesis of "natural," genetically based difference and one that invokes environmental influences. Couched in these terms, however, the clash of views has all the earmarks of a sterile, even boring, debate. Without trying to resolve competing hypotheses, let's simply look at the information we have at hand about the development of verbal and spatial abilities in little boys and little girls.

To begin with, there is ample evidence that visual-spatial abilities are at least in part learned skills. As an example, consider the fact that first-grade boys do somewhat better than do first-grade girls on embedded figures and blocks tests if neither has seen such tests before. Allowed a bit of practice, however, the girls improve enough to catch up, although the boys' scores do not change much. Researchers conclude from such studies that first-grade boys have already honed these skills so that additional practice does not lead to improved performance.[53] Why boys might be more practiced is anyone's guess, but since young boys and girls have quite different play experiences, one can at least construct a plausible hypothesis. Traditional male games such as model construction, block building, and playing catch might play a key role in developing visual-spatial skills, yet the relationship between play activities and the acquisition of spatial abilities has received scant attention from the research community.

Studies done on older children also reveal that three-dimensional visual skills can be learned. In one case a researcher assessed the performance of teenage students as they began a drafting course. The expected sex differences were found, but disappeared six weeks into the semester as the young women improved.[54] In another case teenagers showed a positive correlation between performance on tests of visual-spatial skill and the number of drafting and mechanical-drawing courses taken.[55] The sparse literature on the relationship between formal skill training (through certain types of course work) and informal (through certain types of play) suggests that girls often do not fulfill their skill potential, but that it would be relatively easy to help them do so. The hypothesis that certain kinds of play and school activities can improve girls' visual-spatial skills is eminently testable, but more research support is needed for scientists who are interested in carrying out such investigations.

It seems unlikely, however, that play and mechanical drawing are the only contributors to the development of visual-spatial skills. Some research suggests that children who experience more independence and less verbal interaction are likely to develop strong spatial skills, a result that dovetails with information obtained from anthropological studies. In a village in Kenya, children who undertook tasks that led them away from home, such as shepherding, performed better on several measures of visual-spatial ability than children remaining close to home, suggesting that children who have a wider range of environmental experiences develop richer skills.[56] Cross-cultural studies of sex-related differences in spatial functioning reveal two additional skill-learning components. Anthropologist J. W. Berry compared the abilities of Eskimos, Scots, and the Temne people of Sierra Leone, pointing out the enormous differences in visual environment they encounter. Eskimo country is open and evenly landmarked (snow covers many potential reference points), while the Temne land is covered with vegetation of various colors. The Eskimo, in order to hunt over large, relatively featureless areas, learns to be aware of minute detail. In fact, the Eskimo language is rich in words describing geometrical-spatial relationships. It is not surprising, then, that Eskimos outperform Temnes in tests of spatial ability.[57]

Child-rearing practices also differ greatly in the two cultures. Eskimos raise their children with unconditional love, only rarely resorting to physical or verbal punishment. In contrast, the Temne emphasize strict discipline, acceptance of authority, and conformity. Eskimo girls are allowed considerable autonomy, while Temne girls are raised even more strictly than the boys in this highly disciplined society. Interestingly, no sex-related differences in spatial abilities show up in the Eskimo population, although marked differences appear between Temne males and females. Berry also compared other societies, including some traditional hunting cultures, with ones undergoing Westernization.[58] In the traditional cultures there were no sex differences in spatial visualization, but differences did appear in some of the transitional ones. One hypothesis that emerges from such work is that sex-related differences in visual-spatial activities are strongest in societies in which women's social (public) roles are most limited, and that these differences tend to disappear in societies in which women have a great deal of freedom. Along these lines consider that in the United States, sex-related differences in both mathematics and spatial abilities may be changing as opportunities and roles for women change. The curricula of primary and secondary schools have become less sex-segregated with the development of equal athletic facilities and both boys and girls taking shop, typing, mechanical drawing, and home economics. As these changes continue, there is no reason to believe that sex-related differences will remain constant and every reason to assume that studies done in 1955 and in 1985 will have different outcomes.

How can we sum up some of the factors influencing the acquisition of spatial skills? Early child-parent interactions may well be involved. Plenty of studies show that parents treat boys and girls differently. Mothers are more likely to repeat or imitate vocalizations from a girl baby than from a boy baby, and they are also more likely to try to distract a male infant by dangling some object in front of him.[59] Individual personality differences also influence parent-child interactions. Preschool children have different play habits. Boys usually explore more and stay away from their parents for longer periods of time than do girls, and certainly differences in games, toys, and amount of exploration could account in part for differences in the development of spatial skills. Girls often wear physically restrictive clothing, such as frilly, starched dresses and patent leather shoes, which contributes to their more physically limited environment. As children grow older they also learn more about sex-appropriate behavior. Pressures to conform are especially strong during the teenage years, when small sex-related differences in spatial skills first consistently appear. Visual-spatial skill-dependent activities ranging from shop and mechanical drawing to mathematics and engineering are also stereotyped male strongholds, daunting to even the most talented girls. Thus the many complex components of sex-role stereotyping may be superimposed upon and may interact with earlier developmental events. In short, there is not any *one* cause of sex-related differences in visual-spatial skills. There are *many* causes. Only future research will tell which are truly significant.

The knowledge that aspects of male/female socialization very likely influence the development of male/female differences in spatial skills should not, of course, rule out the possibility that innate biological factors contribute to such differences as well. The argument I have made to this point is twofold: (1) the size of sex differences is quite small, and (2) a complex of environmental factors has *already been demonstrated* to influence the development of visual-spatial skills. Do we then even *require* the hypothesis of biologically based differences to explain our observations? I think not, although I remain open to the idea that some small fraction of an already tiny sex-related difference could result from hormonal differences between male and female.

A Plethora of Theories: Biological Storytelling

Despite the small size of sex-related differences in verbal and spatial skills, their existence has elicited numerous studies aimed at explaining them on the basis of biological differences between the sexes. Scouring the ins and outs, curves and shapes, capacities and angles of the human brain, hoping to find traits that differ in the male and female is a pastime in which scientists have engaged for more than a century. Early studies, which discovered that male brains were larger than female brains, concluded that the female's smaller size resulted in her inferior intelligence. This logic, however, ran afoul of the "elephant problem": if size were the determinant of intelligence, then elephants and whales ought to be in command. Attempts to remedy this by claiming special importance for the number obtained by dividing brain size by body weight were abandoned when it was discovered that females came out "ahead" in such measurements. The great French naturalist Georges Cuvier finally decided that intellectual ability could best be estimated by the relative proportions of the cranial to the facial bones. This idea, however, ran aground on the "bird problem," since with such a measure birds, anteaters, and bear-rats turn out to be more intelligent than humans.[60] Some brain scientists believed that the frontal lobe of the cerebrum (the part that sits in the front of the head just above the eyebrows—see figure 2.3) was an important site of perceptive powers and was less well developed in females than in males. Others argued that even individual brain cells differed in males and females, the cerebral fibers being softer, more slender, and longer in female brains.

As neuroanatomists became more and more convinced that the frontal lobe was the repository of intelligence, an increasing number of reports appeared claiming that this lobe was visibly larger and more developed in males. One report, in 1854, concluded that Woman was *Homo parietalis* (after the parietal lobe, which lies toward the back and to the side of the head—figure 2.3) and Man *Homo frontalis.* In time, however, the parietal rather than the frontal lobe gained precedence as the seat of the intellect, a change

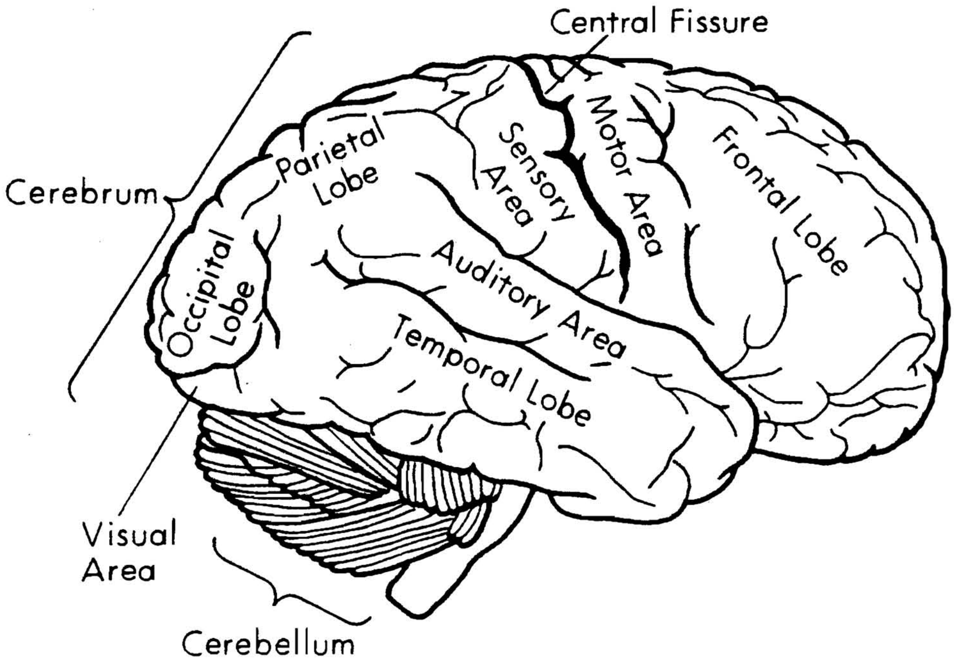

FIGURE 2.3
Cerebrum and Cerebellum
Localization of function in the human cerebral cortex. Only the major convolutions of the cortex are drawn. They are remarkably constant from individual to individual, and provide landmarks in the task of mapping the distribution of special functions in different parts of the cortex. Note especially the sensory area which lies posterior to the central fissure (or convolution), and the motor area which lies anterior to the central fissure.

accompanied by an about-face on sex differences in the brain: "The frontal region is not, as has been supposed, smaller in woman, but rather larger relatively. But the parietal lobe is somewhat smaller."[61]

Other female brain "deficiencies" found in this same period include the supposedly smaller surface area of the corpus callosum (a mass of nerve fibers that connect the left and right halves of the brain), the complexity of the convolutions of the brain, and the rate of development of the fetal cerebral cortex. These beliefs were held until 1909, when anatomist Franklin Mall used new statistical techniques developed in the budding fields of psychology and genetics to refute the existence of such differences.[62]

From the period following the end of World War I through the first half of the 1960s, psychologists and biologists developed few additional theories. A new outbreak began in the late 1960s, and since then hypotheses have come and gone rapidly. The popular press fanfares each entry with brilliant brass, bright ribbons, and lots of column space, but fails to note when each one in its turn falls into disrepute. The number and variety of theories that have come our way in the past fifteen years are truly remarkable, and an account of their advent, an analysis of their scientific basis, and a view of their demise instructive. I've listed seven of these biological hypotheses in table 2.4, along with their current status and references for studying them in more detail. The pages that follow focus attention on two of the most popular and currently active ideas—the claim that spatial ability involves a pair of X-linked genes and that male and female brains have different patterns of lateralization.

Space Genes

In 1961 Dr. R. Stafford suggested that humans carry two different X-linked genetic sites, one influencing mathematical problem-solving ability and the other affecting spatial ability.[63] Similar to Lehrke's X-linked variability hypothesis, Stafford's theory proposed that males need inherit only one X chromosome in order to excel in math or spatial tasks, while females need a math and a space gene on each X chromosome, a less frequent possibility.

If his hypothesis were true, one would expect a smaller percentage of females than of males to be good at math and spatial activities. A number of studies have tested predictions about parent-child correlations in mathematical problem solving—predictions that geneticists made from Stafford's theory. Before 1975 some small-sized studies seemed to support Stafford's contention, although the experimental results rarely obtained statistical significance (unless, in a highly unusual procedure, groups from different studies done by different research groups were pooled to increase sample size). Large studies performed since the mid-1970s have failed to find evidence to support the X-linked hypothesis. The most recent study I found concluded that "[s]ince the previous evidence from small studies cannot be replicated, it appears that the X-linkage hypothesis is no longer tenable."[64] Even more recently, Dr. Hogben Thomas, a researcher at Pennsylvania State University, pointed out that the approach used to test Stafford's hypothesis may be fundamentally flawed and that the X-linkage theory of spatial ability may simply be untestable.[65]

Furthermore, there is a very different source of data that appears to contradict the X-linked hypothesis, one recognized some years ago by two other scientists, Drs. D. R. Bock and D. Kolakowski.

TABLE 2.4

Biological Theories to Explain Sex-related Cognitive Differences

Year of Initial Publication	*Name of Theorist*	*Basic Tenet*	*Current Status of Theory*
1961	Stafford[g]	Spatial ability is X-linked and thus males show it more frequently than do females.	Clearly disproven,[h] although still widely quoted. Current authors still feel the necessity to argue against this genetic hypothesis.
1966	Money and Lewis[c]	High levels of prenatal androgen may increase intelligence.	Disproven by Baker and Ehrhardt in 1974.[d]
1968	Broverman et al.[e]	Males are better at "restructuring" tasks, due to lower estrogen levels, greater activity of "inhibitory" parasympathetic nervous system.	Actively critiqued in early 1970s. Not cited in current literature.[b]
1972	Buffery and Gray[f]	Female brains are more lateralized than male brains; greater lateralization interferes with spatial functions.	No evidence; not currently an important view.
1972	Levy[k]	Female brains are less lateralized than male brains, less lateralization interferes with spatial functions.	Currently in vogue; dominates the field despite a number of cogent critiques; no strong supporting evidence.
1973	Bock and Kolakowski[l]	Supplements Stafford's theory. Sex-linked spatial gene is expressed only in the presence of testosterone.	Clearly disproven,[h] although still widely quoted. Current authors still feel the necessity to argue against this genetic hypothesis.

TABLE 2.4 *(continued)*

1976	Hyde and Rosenberg[e]	High blood uric-acid levels increase intelligence and ambition. Males have more uric acid than females.	Not widely cited, no supporting evidence.[f]

[a] Donald M. Broverman, Edward L. Klaiber, Yutaka Kobayashi, and William Vogel, "Roles of Activation and Inhibition in Sex Differences in Cognitive Abilities," *Psychological Review* 75(1968):23-50.
[b] Julia A. Sherman, *Sex-Related Cognitive Differences: An Essay on Theory and Evidence* (Springfield, Ill.: Charles C Thomas, 1978); Mary Parlee, "Comments on 'Roles of Activation and Inhibition in Sex Differences in Cognitive Abilities' by Broverman *et al.*," *Psychological Review* 79(1972):180-84; G. Singer and R. Montgomery, "Comment on Roles of Activation and Inhibition in Sex Differences in Cognitive Abilities," *Psychological Review* 76(1969):325-27; Donald M. Broverman, Edward L. Klaiber, Yutaka Kobayashi, and William Vogel, "A reply to the 'Comment' by Singer and Montgomery on 'Roles of Activation and Inhibition in Sex Differences in Cognitive Abilities'," *Psychological Review* 76(1969):328-31.
[c] John Money and V. Lewis, "Genetics and Accelerated Growth: Adrenogenital Syndrome," *Bulletin of Johns Hopkins Hospital* 118(1966):365-73.
[d] Susan W. Baker and Anke Ehrhardt, "Prenatal Androgen, Intelligence, and Cognitive Sex Differences," in *Sex Differences in Behavior*, ed. R. C. Friedman, R. M. Richart, and R. L. Van de Wiele (New York: Wiley, 1974).
[e] J. S. Hyde and B. G. Rosenberg, *Half the Human Experience: The Psychology of Women* (Lexington, Mass.: D.C. Heath, 1976).
[f] Julia A. Sherman, *Sex-Related Cognitive Differences: An Essay on Theory and Evidence* (Springfield, Ill.: Charles C Thomas, 1978).
[g] R. E. Stafford, "Sex Differences in Spatial Visualization as Evidence of Sex-Linked Inheritance," *Perceptual and Motor Skills* 13(1961):428.
[h] Robin P. Corley, J. C. DeFries, A. R. Kuse, and Steven G. Vandenberg, "Familial Resemblance for the Identical Blocks Test of Spatial Ability: No Evidence of X Linkage," *Behavior Genetics* 10(1980):211-15.
[i] D. R. Bock and D. Kolakowski, "Further Evidence of Sex-Linked Major-Gene Influence on Human Spatial Visualizing Ability," *American Journal of Human Genetics* 25(1973):1-14.
[j] A. W. H. Buffery and J. Gray, "Sex Differences in the Development of Spacial and Linguistic Skills," in *Gender Differences: Their Ontogeny and Significance*, ed. C. Ounsted and D. C. Taylor (London: Chirhill Livingston, 1972).
[k] Jerre Levy, "Lateral Specialization of the Human Brain: Behavioral Manifestation and Possible Evolutionary Basis," in *The Biology of Behavior*, ed. J. A. Kiger Corvalis (Eugene: University of Oregon Press, 1972).

Rather than discard Stafford's hypothesis, however, they modified it, turning counter-evidence into support.[66] On occasion, individuals are born with no Y chromosome. Doctors call them XOs. Since they are born with female genitalia, XO individuals are usually raised as girls, and in many respects are quite normal, although they can sometimes be recognized by their short height, webbed neck, and failure to develop fully at puberty. XO individuals, said to have Turner's Syndrome (named after the physician who first described it), have spatial abilities well below the normal range, a fact that contradicts Stafford's hypothesis. If the X-linked hypothesis were correct, Turner's Syndrome patients would not differ from XY males, expressing their spatial ability more frequently than XX females, because their single X chromosome is not "covered" by a second X. In order to get around this uncomfortable fact, Bock and

TABLE 2.5
Verbal and Performance IQ's of Individuals with Sex Chromosome and/or Hormone Abnormalities

Number of Individuals Tested	*Sex of Rearing*	*Sex Chromo-some; Constitution*	*Adult Hormone Levels*	*Average Verbal IQ Scores*	*Average Perfor-mance IQ Scores*
45	F	XO	low estrogen low androgen	106	86
15	F	XY	intermediate estrogen, androgen-insensitivity	112	102
3	M	XY	intermediate estrogen, androgen-insensitivity	117	119
23	M	XXY	intermediate estrogen, intermediate androgens	105	88
12	M	XXY	intermediate estrogen, intermediate androgens	66	76
20	M	XYY	unknown	79	88

NOTE: Julia Sherman, *Sex-Related Cognitive Differences: An Essay on Theory and Evidence* (Springfield, Ill.: Charles C Thomas, 1978), 84. Courtesy of Charles C Thomas, Publisher.

Kolakowski proposed that the space gene is not only X-linked but is also sex-limited, depending for its expression on high androgen levels which circulate throughout the body in higher concentrations in men than in women. (A familiar example of a sex-limited gene is baldness, expressed only in men because it depends for its expression on higher androgen levels than are present in most females.)

The sex-limited hypothesis represents a clever stab at saving the game, but it too runs counter to the data. Psychologist Julia Sherman has offered the most succinct demolition of the theory, and table 2.5 represents some of her work.[67] Turner's Syndrome patients have lower than normal estrogen (a hormone found in higher concentrations in females) and androgen levels. Bock and

Kolakowski argue that the gene coding for spatial ability requires a certain cellular concentration of androgen in order to function. In XO individuals, they suggest, too little androgen is present, and thus Turner's Syndrome girls have poor spatial abilities. To shore up their position, they cite another study of individuals with androgen insensitivity syndrome (AIS)—people who possess both X and Y chromosomes but who are unable to respond to androgens. AIS patients are often born with femalelike genitalia. Fifteen such persons, all raised as females, were tested and obtained an average Verbal IQ of 112 and Performance IQ of 102.* Although both scores fit in the normal range, Bock and Kolakowski inferred from this test that inability to respond to androgen lowered spatial IQ. But who can say whether the Verbal IQ might not have been abnormally high rather than the spatial IQ being unusually low? Furthermore, Bock and Kolakowski ignore additional data from the same study. Three AIS patients reared as *males* scored well above the normal range on both verbal and spatial IQ tests. If androgen really improves the expression of spatial genes, how is it that three androgen-insensitive individuals performed above average on a spatial test?[68]

Chromosomal abnormalities affect mental functioning. All people born with either one too many or one too few chromosomes show some degree of mental impairment. The information in table 2.5 makes this clear. Only AIS patients, who have a normal chromosome complement, score consistently in the normal range on both Verbal and Performance IQ. The data in table 2.5 thus suggest that good performance correlates with normal chromosome complements, *not*—as Bock and Kolakowski suggest—with hormone levels. By any scientifically acceptable standards, this attempt to save the X-linked space gene theory fails.

As a study in the sociology of science, however, the Stafford hypothesis remains interesting. From the point of view of a geneticist, the idea that two specific genes govern a complex, continuously varying trait is dubious to begin with. As we have just seen, the available data is either categorically inappropriate or lends no support to the idea. Yet since its initial publication in 1961, the X-linkage hypothesis has shown considerable tenacity, appearing as fact in some textbooks and showing up in highly political articles as part of larger arguments about the genetic incapacity of females for certain sorts of work.[69] The real fact is that many people, both

* Performance IQ (see p. 32) is used by some scientists as a measure of spatial ability, although it is not a test designed for this use.

scientists and nonscientists, just plain *like* the idea and go to considerable lengths to salvage it because it fits so neatly into the entrenched stereotype of feminine inferiority. It constitutes a not uncommon example of how social views influence the progress of science.

Left versus Right: The Psychologists' Sleight of Hand

Functionally, humans have two brains. The idea has become sufficiently commonplace to appear even in the daily newspaper cartoons (see cartoon, above). While the left hemisphere of the brain appears specialized to carry out analysis, computation, and sequential tasks, in the right half resides artistic abilities and an emotional, nonanalytic approach to the world. As originally developed, the idea of brain hemisphere differentiation said nothing about sex differences. But it didn't take long for some scientists to suggest that left–right brain hemisphere specialization could "explain" supposed male/female differences in verbal, spatial, and mathematical ability. The development, dissemination, and widespread acceptance of such ideas provides a second and still very active example of science as social policy.

Humans, like all vertebrates, are bilaterally symmetrical. Although our left and right sides represent approximate anatomical mirror images of one another, they are not equally competent at the many daily activities in which we engage. Each of us has a particular hand and foot preference, using one side of the body more skillfully than the other to, among other things, kick a football, throw a baseball, write, or eat. Such functional asymmetry provides one tangible measure of a complex and poorly understood division of labor between the two sides of the brain. Looking down on the brain from above, one sees the convoluted folds of the right and left halves of the cerebral cortex connected by an enormous mass of nerve fibers, the corpus callosum (see figure 2.4). Each brain hemisphere controls movements executed by the opposite side of the body. Most people are right-sided, that is, they perform most major activities with the right side of the body, and can thus also be thought of as left-brained. The common scientific belief is that the left hemisphere controls the right side of the body's activities. The converse is probably true for many but not all left-siders.

Our understanding of how the brain mediates our behavior remains superficial, yet a few general observations are possible. For starters, we know that different portions of the cerebral cortex have primary responsibility for particular functions. For example, a region in the posterior part of the cortex (the part located at the back of the head, just above where the skull and neck hook together) enables us to see (and is thus referred to as the *visual cortex*). The region of the cortex responsible for hearing is located further forward along the left side of the head, and numerous other functions take up primary residence in other regions of the brain, as figure 2.4 illustrates.

A second aspect of brain function involves the notion of cerebral dominance. For many years scientists thought of the hemisphere controlling our preferred side as the major hemisphere, and the other as a minor, less competent half. During the 1950s a change in that viewpoint evolved, because discoveries made it clear that the halves of the brain were not so much dominant and dominated

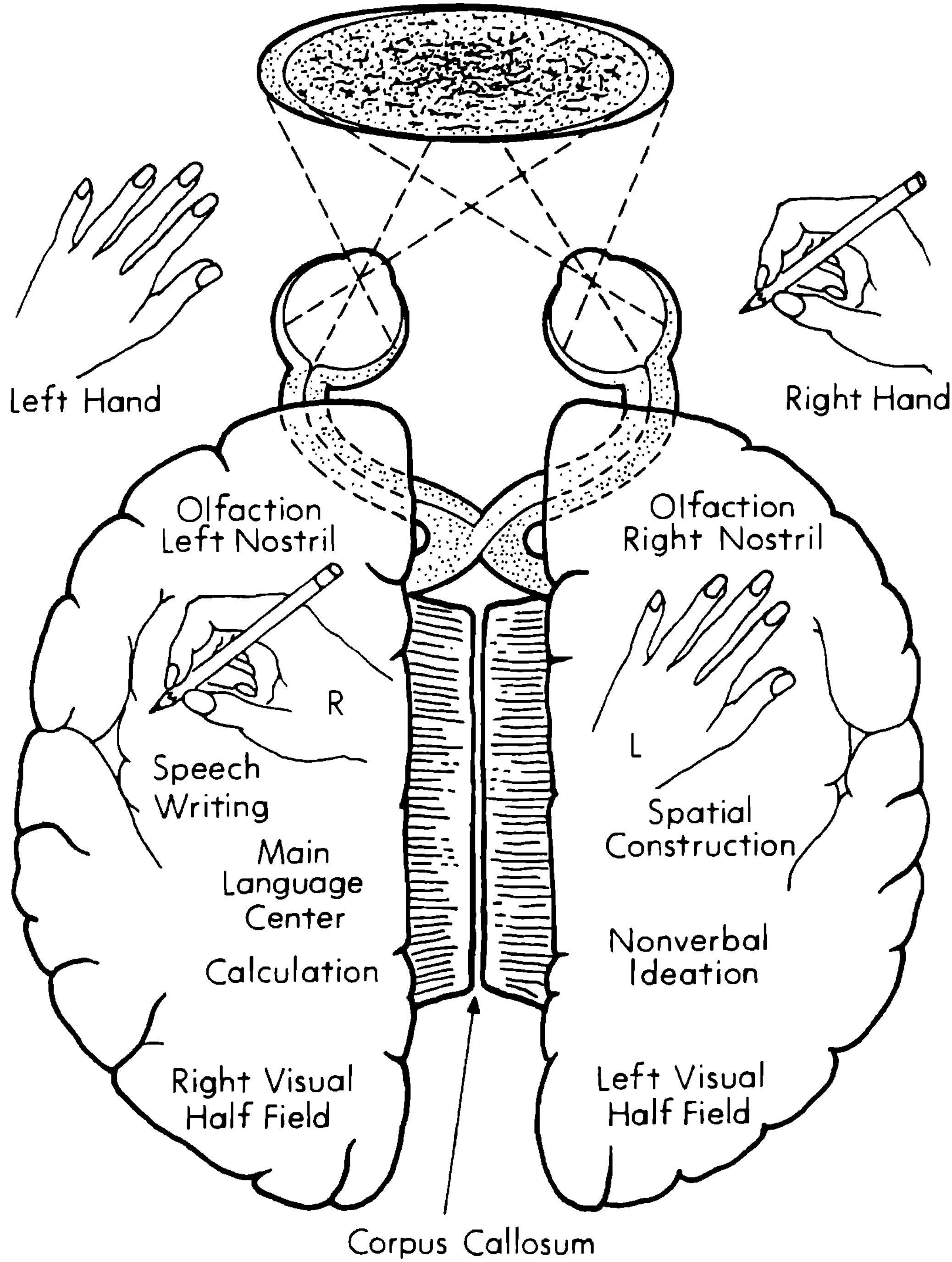

FIGURE 2.4

The Right and Left Hemispheres of the Brain and their Functions

NOTE: Richard Restak, *The Brain, The Last Frontier* (New York: Warner, 1979), 190. Copyright © 1979 by Richard M. Restak. Reproduced by permission of Doubleday & Company, Inc.

as they were different. Some physicians tried, with a modicum of success, to control severe cases of epilepsy by cutting the fibers of the corpus callosum, thus separating the connections between the two halves of the brain. Because patients receiving such operations appeared under most circumstances to function normally, some time passed before Dr. Roger Sperry, a well-known neurobiologist, and a number of his students designed special tests which revealed that in such "split-brain" individuals the different halves of a supposedly symmetrical brain had very different capabilities.[70] They found, for example, that if a blindfolded split-brain patient picks up a pencil in the left hand (controlled by the right brain) he or she can neither name nor describe it, although such a patient can easily do so while holding the pencil in the right hand. Such an observation suggests that language—the ability to read and speak—is localized primarily on the left side of the brain. The fact that the same patient (still blindfolded) can use his or her sense of touch to select a pencil from among a number of other objects shows that the ability to recognize pencils remains. But when the fibers connecting the two halves of the brain are severed, there is no transfer of this recognition from the right side of the brain to the left, where the ability lies to name what the patient touches. The same is true of visual perception. With the right eye covered, these patients cannot read or copy words flashed in front of the left eye (connects to the right hemisphere), although they recognize the content. One of Sperry's patients, for example, gave an embarrassed giggle when a nude figure flashed before her left eye, but she could not explain why she had laughed.

As a result of many studies on both split-brain patients and people in whom one brain half has been damaged by a stroke, cancer, or accident, scientists now make the following generalizations about normal, *right-handed* people. (Little is yet understood about left-sidedness.) The left side of the brain has the capability for all verbal activities, and for analytical, mathematical, and sequential information processing. It is sometimes called the analytical brain. The right side specializes in spatial skills and holistic, nonverbal, Gestalt processing, including musical ability. A concert conductor who, due to a stroke, was almost completely unable to speak but could nevertheless continue to conduct his own orchestra, provides a dramatic illustration of this hemispheric specialization.

The fact that the two halves of the brain specialize for different intellectual activities is of both theoretical and practical importance.

Humans are the only primates exhibiting handedness or hemispheric specialization,[71] and some speculate that the phenomenon may have evolved as part of the evolution of speech and tool making. But consideration of the discoveries that have located certain functions in particular regions of the brain requires some caution. We have yet to understand how the brain thinks, and we know nothing about how, or even whether, the brains of two individuals—one skilled in mathematics and the other a talented fiction writer, for example—differ. To illustrate, fantasize for a moment about the return to earth of Benjamin Franklin, the inventor, scientist, and patriot. The year is 1985. On his return Franklin observes immediately that our roads crawl with mechanical horses (cars). Curious, he experiments to discover how they work. First he removes different parts of the car, observing that the removal of a wheel makes the ride bumpy, draining of the brake fluid makes it difficult to stop, and removal of the battery or engine prevents forward motion altogether. Although he thus localizes some functions, he uncovers little information about their mechanisms or about the natures of either batteries or internal combustion engines. Only much more painstaking analyses could reveal that. Ben Franklin reincarnate might quickly identify the seat of motive power, but he could not as easily uncover its mechanism of function.

In finding that different halves of the cerebrum specialize for different functions, we have identified a major seat of power but have learned little about how it operates. A 1980 article in *Science* magazine further illustrates how little we know. It contains a report on a British university student with an IQ of 126 who has first-class honors in math, is socially normal, yet has hardly any nerve cells in his cerebral cortex.[72] This and similar medical reports suggest that the task of understanding the mechanisms by which the brain performs intellectual functions still lies far beyond our reach.

The excitement elicited by Sperry's discoveries has led to a somewhat unbalanced view of how the brain works. As Sperry himself comments in his Nobel Laureate address: "The left-right dichotomy . . . is an idea with which it is very easy to run wild."[73] He cautions that other divisions in the brain (such as front/back, up/down) may also have unrecognized importance but, most important, he stresses that the brain operates as a coherent whole, a closely integrated unit. Overemphasis on the separate abilities of particular brain regions easily leads us to neglect to inquire into the function of the integrated whole.

Sperry also suggests that each human brain may be different enough to defy generalization: "The more we learn, the more we recognize the unique complexity of any one individual intellect and the stronger the conclusion becomes that the individuality inherent in our brain networks makes that of fingerprints or facial features gross and simple by comparison."[74] Since scientists work on the assumption that they can generalize and predict, Sperry's suggestion is quite unsettling. If he is right, then entire subfields of psychology and neurobiology may have to change their approach and their focus.

One last point about hemispheric specialization: cerebral lateralization is not immutable during childhood. In children who incur brain damage on only one side, the undamaged hemisphere can carry out all of the functions of an uninjured brain, although in adults this is not the case. It seems at least plausible, then, that the developmental environment of childhood plays an important role in the attainment of adult hemispheric capacities.[75]

Not long after the discovery of hemispheric specialization, some scientists began using it to explain both the supposed female excellence in verbal tasks and the male skill in spatial visualization. In the past eight years at least four different theories on these skills have appeared, the two discussed here having received the most attention although, interestingly enough, they are mutually incompatible. The first, put forth in 1972 by two psychologists, Drs. Anthony Buffery and Jeffrey Gray,[76] now suffers disfavor. The other, elaborated by Dr. Jerre Levy[77]—who during and after her time as Sperry's student, played an important role in defining the modern concept of hemispheric specialization—is still in fashion. The pages of *Psychology Today*, *Quest*, and even *Mainliner* magazine (the United Airlines monthly) have all enthusiastically described her theory. Speculation also abounds that sex differences in hemispheric specialization result from different prenatal and pubertal hormonal environments.[78] Since a number of psychologists have pointed to a substantial body of experimental evidence that renders Buffery and Gray's hypothesis untenable,[79] we will consider only Levy's views.

Levy hypothesizes that the most efficiently functioning brains have the most complete hemispheric division of labor.[80] Women, she suggests, retain a capacity for verbal tasks in both hemispheres.

In other words, they are less lateralized for speech than are men. When verbal tasks in women "spill over" to the right side of the brain, they interfere with the right hemisphere's ability to perform spatial tasks.* Men, in contrast, have highly specialized brain halves—the left side confining its activities solely to verbal problems, the right side solely to spatial ones.

Let's suppose for a moment that male and female brains do lateralize differently and ask what evidence exists to suggest that such differences might lead to variations in performance of spatial and verbal tasks. The answer is, quite simply, none whatsoever. Levy derives the idea not from any experimental data but from a logical supposition. In her later work[81] she takes that supposition and "reasons" that "a bilaterally symmetric brain would be limited to verbal or spatial processing. . . ." Recently psychologist Meredith Kimball reviewed the small number of studies that might act as tests of Levy's logical supposition and came up empty-handed, concluding that there is no evidence to support the key assumption on which Levy builds her hypothesis.[82]

Nevertheless, the proposal that men and women have different patterns of brain lateralization has provoked enormous interest. Scientists have published hundreds of studies, some done on normal subjects and others derived from subjects with brain damage due to stroke, surgery, or accident. The idea that verbal function might operate differently in male and female brains came in part from a long-standing observation: among stroke victims there appear to be more men than women with speech defects serious enough to warrant therapy. There may be a number of explanations for why men seek speech therapy more frequently than do women. To begin with, more males *have* strokes.[83] Also, it is possible that males seek remedial therapy after a stroke more frequently than do females. And strokes may affect speech less severely in females because females have better verbal abilities *before* the illness.[84]

Some researchers have attempted to sort out these possibilities, but a controlled study of stroke victims is extremely difficult. One reason is that there is no way of knowing for sure whether male and female victims under comparison experienced exactly the same type of brain damage. Even comparisons of individuals who had surgery performed on similar parts of their brains are probably

* The theory actually holds that left-handed men resemble women in this regard. The experimental support for her conclusions about left-handed men has been roundly criticized, especially by J. Marshall (see note 79).

quite misleading because of variation in brain morphology from individual to individual. It would be possible to ascertain the exact regions of the brain affected only by looking at microscopic sections of it, a practice that is routine in animal experiments but would of course be impossible with live human beings. Extensive reviews of clinical studies reveal a great deal of controversy about their meaning, but little in the way of strong evidence to support the idea that women have bilateralized verbal functions.[85] Consider the statement of a scientist who believes her work to *support* the differential lateralization hypothesis:

> Neither do the data overwhelmingly confirm that male brains show greater functional asymmetry than female brains. . . . One must not overlook perhaps the most obvious conclusion, which is that basic patterns of male and female brain asymmetry seem to be more similar than they are different.[86]

If this is the kind of support the proponents of sex differences in laterality put forward, then it is amazing indeed that the search for sex-related differences in brain lateralization remains such a central focus of current research in sex-related cognitive differences.

In addition to looking at patients with brain damage, researchers have tested Levy's hypothesis using normal individuals. The most common way of measuring hemispheric specialization in healthy people is by the dichotic listening test. To look for language dominance, experimenters ask the subject to don a set of headphones. In one ear the subject hears a list of numbers, while in the other he or she simultaneously hears a second, different list. After hearing the two lists, the subject (if not driven nuts) must remember as many of the numbers as possible. Usually subjects can recall the numbers heard on one side better than those heard on the other. Some experimenters believe that right-ear excellence suggests left-hemisphere dominance for verbal abilities and vice versa, but this conclusion ignores other possibilities. Individuals who take the tests may develop different strategies, for instance, deciding to try to listen to both sets of numbers or to ignore one side in order to listen more closely to the other.

Some scientists have reported sex differences in performance on dichotic listening tests, but three recent reviews of the research literature indicate a lack of solid information.[87] Many studies show no sex differences and, in order to show any differences at all, large samples must be used, all of which suggests that same-sex disparities may be larger than those between the sexes. One reviewer ends her article with the following comments:

> Any conclusions rest on one's choice of which studies to emphasize and which to ignore. It is very tempting to . . . argue that there are no convincing data for sex-related differences in cognition or cerebral lateralization. . . . In fact, what is required is better research.[88]

Analogous methods exist for studying visual lateralization. Tests utilize a gadget called a tachistoscope, through which a subject looks into a machine with an illuminated field. The machine flashes different items in front of either the right or the left eye, and the subject tries to identify as many as possible. Nonverbal images such as dots (as opposed to words or letters) suggest some left-field (right-hemisphere) advantages for men, but here too the data vary a great deal. For example, many (but not all) studies show male left-eye advantages for perception of photographed faces, scattered dots, and line orientations, but no sex differences for the perception of schematic faces, depth, or color.[89] In addition, the fundamental question of whether such tests have anything at all to do with brain lateralization continues to cloud the picture.

Although there is no solid evidence for the idea that females are more bilateral than males in verbal functioning, there *does* seem to be evidence that females use their left hemisphere (their verbal hemisphere) more frequently to solve visual-spatial problems. As Sherman points out, this does not necessarily imply a sex-related difference in brain organization, but could instead reflect different problem-solving strategies. For whatever reasons, females may prefer to use verbal approaches to the solution of spatial problems. In fact, several studies show different *approaches* to nonverbal problem solving, but find no overall sex differences in performance. In other words, males did not have a better final outcome; they just reached the same end using a different means than did the females.[90]

As of this writing, a number of hypotheses to explain such strategic differences are actively competing with one another. Sherman, for example, suggests what she calls the "bent twig" hypothesis,[91] proposing that girls develop their language ability a bit earlier than do boys, thereby initiating a chain of reactions that give females progressively greater language skills. Because girls talk sooner, parents may talk more with and further develop their daughters' language skills. And because of their facility, little girls may choose verbal mediation over so-called "Gestalt" processes for the solution of visual-spatial problems. Sherman entertains the possibility that early verbal development in young girls is a true biological sex difference, but it is also possible that if girls learn to talk earlier than do boys it is because adults in their environment interact with them more often and intensively with the spoken word.

If there remains uncertainty about different maturation rates in early language acquisition, there is some clarity in the fact that on the average, girls reach puberty and adult size two to three years before boys. This developmental rate difference forms the basis of another hypothesis, put forth by psychologist Dr. Deborah Waber.[92] She provides evidence that late maturers, *male or female*, have more highly lateralized brains. She thus accounts for any small male/female differences in lateralization by the fact that males, on the average, grow more slowly. Not all studies, however, agree either about the correlation of maturation rate and spatial abilities or about the interpretation of any such correlation, and Waber's suggestion remains under active investigation.[93]

Finally, there is a series of suggestions, not yet in the form of full-dress hypotheses, about the ways in which physical activity might affect the development of visual-spatial skills. What kinds of cognitive capacities develop from active play—tree climbing, running, throwing, batting, and catching a ball? Virtually no information exists on this issue. Yet if scientists are truly interested in how cognitive abilities develop (in a little boy or a little girl), these questions surely require investigation.

Biological Calculus: Do the Sexes Differ in Mathematical Ability?

A few years ago, a friend phoned me for some advice. His ten-year-old daughter was upset because she had just heard on the radio about the hot new discovery that boys are genetically better at math than are girls. Girls, she had heard, would be less frustrated if they recognized their limits and stopped their fruitless struggle to exceed them.

"Daddy," she had said, "I always wanted to be a math professor like you. Does this mean I can't?"

My friend wanted to know if I had read the article. "Is it true? What can I tell my daughter?"

Just two days before, I had seen the same report in the *New York Times.*[94] One day before, the mail carrier had dropped through my mail slot the issue of *Science* magazine containing the short research article by Drs. Camilla Benbow and Julian Stanley, which I had seen summarized in the *Times.*[95] Within the week, radio advertisers hawked the latest issues of *Time* and *Newsweek,* telling me even as I sleepily brushed my teeth in the morning to buy the magazines because they contained new evidence about "male math genes."[96] And so it went. The *Time* article even had an illustration in case we couldn't get the written message. The cartoon portrayed a girl and a boy standing in front of a blackboard, with a proud, smug-looking adult—presumably a teacher—looking on. The girl frowns in puzzlement as she looks directly out at the reader. On the blackboard in front of her stands the multiplication problem 8 × 7, which she is clearly unable to solve. The boy looks with a toothy smile toward the adult, who gazes back at him. The cause for the satisfaction? The correct answer to the multiplication problem 7,683 × 632. Interpreting the image does not require a degree in art history, and the aftershocks from the *Science* article and subsequent press coverage still rumble beneath our feet.

Clearly, math and sex is a hot topic. The question is, what's all the fuss about? The issue is part of both a national and individual crisis. The 1983 report of the National Science Board's Commission on Precollege Education in Mathematics, Science and Technology puts it this way: "Our children could be stragglers in a world of technology. We must not let this happen; America must not become an industrial dinosaur. We must not provide our children a 1960s education for a twenty-first-century world."[97]

Researcher Lucy Sells labels high school mathematics achievement a "critical filter" which limits the choices of study available to women and minorities who enter college,[98] and others have pointed out how mathematics requirements restrict entry to the high-paid field of engineering.[99] A recent counseling session I had with a female student interested in biology vividly illustrates the point. The student wanted advice about choosing her major. She had taken a variety of nonscience courses during her first couple of years in college and was certain that she did not want to become a high-powered professional, preferring instead a goal of working one-on-one with people in city neighborhoods. "And," she said, "I really like biology." Fresh from reading the National Science Board's report, I cheerfully suggested that she might translate her enthusiasm for this aspect of science into becoming a science and math teacher at the primary or secondary level. It was then that her face fell. "I haven't had math since my sophomore year in high school," she confessed, "and that seems so long ago, I can't even remember whether it was a course in algebra or geometry."

That left us stuck. I urged her to take the preintroductory level course offered by our math department (pejoratively called "math for poets" by some), with the hope that she could build up enough background to enter the introductory sequence. But I realized that by the time she had done that she would be ready to graduate. The choice she had made to stop studying math in high school now, five years later, had come back to haunt her. The damage was not irremediable but it would take time, and I would be surprised if she ended up deciding to teach math and science, badly needed though she may be.

There are very few hard facts about women and mathematics, but one thing we know for sure is that girls take fewer mathematics courses in high school than do boys.[100] Do they drop out because they are less able to achieve mathematically, or are other factors involved, such as stereotypes about math being a male field, discouragement from parents and teachers, and social pressures? Most educational researchers agree that in an unselected population, boys and girls are equally good at math until the seventh grade. Beyond that, however, the debate becomes mired in confusion. Many studies done before 1974 that claimed to find significant sex-related differences in math achievement failed to use well-matched populations. Instead the boys averaged a larger number of courses taken, and the studies really compared girls who had taken only one or two math courses with boys who had taken three or four. Later work that attempted to control for both the number of math courses and the number of related courses in areas such as mechanical drawing and drafting sometimes found only small sex-related differences favoring boys.[101] The results of studies done on large unselected samples give inconsistent results.[102]

In some of the studies for which sex-related differences in math have been found even among students with the same number of formal math courses, the role of social factors in accounting for such differences has also been measured. Differences in spatial visualization seem to play only a minor role, but other factors, such as the perceived importance of mathematics for future studies (girls less often thought it important), the perception of math as a male field (more male engineers and math professors), active discouragement of girls by teachers and parents (girls more often received negative feedback than boys), all taken together went a long way toward accounting for the small, occasional differences found in mathematics achievement between boys and girls who have taken the same number of math courses.

This being the case, how is it that the Benbow-Stanley report in *Science* provoked such widespread publicity? The authors make use of data obtained from ongoing studies of mathematically precocious youth at Johns Hopkins University. Since 1972 these researchers have run talent searches to find seventh and eighth graders who are unusually good at math, generally students found to perform in the upper 3 to 5 percent of their classes. Of the talented youth identified, 43 percent were girls. As part of their study, Benbow and Stanley gave these seventh and eighth graders the College Board Scholastic Aptitude Test in mathematics. Since such tests are designed for juniors and seniors in high school who are older and who have had more advanced math classes, Benbow and Stanley argued that the exams functioned as achievement tests in mathematical reasoning when given to much younger students. In each of the six years of the study, the results showed that on average girls obtained scores that were between 7 and 15 percent lower than the average score for boys. Furthermore, anywhere from three to ten times more boys than girls score in very high ranges, although there were usually some very high scoring girls. Such are the results; the fight, of course, is about their meaning. Benbow and Stanley point out that in the seventh and eighth grade, most children take the same math courses, so the differences cannot be due to *formal* course taking:

> It, therefore, cannot be argued that these boys received substantially more formal practice in mathematics and therefore scored better. Instead, it is more likely that mathematical reasoning ability influences differential course-taking in mathematics.

After further considering their data, they end their article with the following.

> We favor the hypothesis that sex differences in achievement in and attitude toward mathematics result from superior male mathematical ability. . . . This male superiority is probably an expression of both endogenous and exogenous variables . . . the hypothesis of differential course-taking was not supported. It also seems likely that putting one's faith in boy-versus-girl socialization processes as the only permissible explanation of the sex difference in mathematics is premature.[103]

In a subsequent paper, also published in *Science*, the same researchers added more subjects to their data base, a fact which they believe further substantiates their initial conclusion.[104]

Attacks on Benbow and Stanley's conclusions have been of three types: questions about the validity of the aptitude test, questions about the limitations of looking only at formal mathematical experience, and questions about whether boys and girls receive the same training even within the same math course. The debate over achievement versus aptitude tests is complex and, I feel, a little beside the point.[105] Whether one calls it aptitude, achievement, or reasoning ability, the fact remains that more very bright boys performed exceptionally on Benbow and Stanley's tests than did very bright girls. Benbow and Stanley claim they are doing nothing more than telling it like it is: "It is not the method of science . . . to ignore published facts or provide a forum for subjective judgments and anecdotal evidence."[106] Since they seem willing to take on the Galilean stance of the honest but persecuted scientist in this debate, it is surprising that they fail to cite a number of studies—including both some of their own and ones by other workers in the Johns Hopkins project—that would at the very least dilute the emphasis they place on the idea of "superior male mathematical ability."

For example, they specifically attack psychologists Elizabeth Fennema and Julia Sherman's conclusion about differential course taking; yet those very same researchers in the very same articles write at length about a variety of other factors (parental attitudes, teachers' attitudes, informal mathematics experience), *all* of which contribute significantly to mathematical achievement. Another group of researchers observed thirty-three second-grade teachers as they taught reading and arithmetic in the classroom, finding that teachers spent more classroom time teaching reading to individual girls and less teaching them math. The boys received less direct instruction in reading and more in math.[107] In other words, boys and girls learning together in the same classroom did not receive the same instruction. Benbow and Stanley dismiss this study as irrelevant saying only that it seemed inapplicable to studies of highly talente children.

Furthermore, in their most recent work they cite some of thei own data[108] to support their skepticism about the inability o socialization to account for the reported achievement test difference in talented junior high school students. Surprisingly, though, the dismiss as irrelevant other information they have collected showin that (1) in high school the girls in their study get slightly bette grades in math courses than do the boys,* and (2) when asked abou intended college majors: "The percentage of males reporting tha they intended to major in the mathematical sciences was 15%, whil for females this was 17%."[110]

Dr. Helen Astin looked at the backgrounds of children in th early years of the Johns Hopkins Study and found that "parents o boys admit that they encouraged the boys more by giving then science kits, telescopes, microscopes, or other science-relate gifts."[111] In addition, the parents of mathematically precocious boy had higher educational hopes for them than did the girls' parents Finally, Lynn Fox and Sanford Cohn, also researchers in the John Hopkins Study, find evidence from other aspects of the project t "support the social explanation of sex differences at higher level of ability and achievement."[112] The evidence from these talente youngsters that boys and girls even at the seventh-grade level hav had different experiences with regard to math training and hav developed very different hopes for their futures makes implausibl Benbow and Stanley's underlying assumption that only socializatio events at puberty influence the development of mathematical skil and achievement.

In considering the debate over math ability the question foremos in my mind is, Why the rush to judgment? Benbow and Stanley, although they hedge their bets, clearly assert that boys have greate math ability than do girls. While choosing to simplify the discussio and ignore much of the literature on sex differences in both teaching and informal learning, as well as findings on career goals and hopes, they invite us all to "face facts" and accept the biological nature o sex differences in math ability if that is, indeed, what objectiv science proves.

* When criticized for failing to discuss the discrepancy between achievement i the classroom and scores on SAT tests, Benbow and Stanley dismissed their own finding by attributing it "to the better conduct of girls in school."[109]

We *do* know a great deal about mathematics learning and especially about why girls drop out of math classes.[113] If math and science were required for four years of high school, if girls were actively counseled to consider careers in science and warned about the ways in which dropping out of math limits their future choices, if teachers were made aware of the different ways they treat boys and girls in the classroom, and if there were many more women teaching math and science to our youngsters, the "problem" of women in math would lessen dramatically, and in all likelihood would disappear. To argue for "endogenous" differences, as Benbow and Stanley have, is to argue willy-nilly, not to bother with all of the "exogenous" changes in educational method and quality that we could make with some degree of success right now. At best their call to consider "natural" causes for the sex difference in math is premature. If, once we have reformed our informal and formal systems of mathematics education and career counseling, there remain significant sex differences in mathematics ability, *then* might be the time to wonder about innate sex differences. In the meantime there are a lot of very specific changes to be made in how we educate our young people. What, then, are we waiting for?

A Question of Genius: Some Conclusions

Are men really smarter than women? The straightforward answer would have to be no. Early in this century, scientists argued that there might be more male than female geniuses because male intelligence varied to a greater extent than did female intelligence. This "fact" provided proof positive of the overall superiority of the male mind. Hypotheses in defense of this position still pop up from time to time. They consist of old ideas in modern dress and are unacceptable to most mainstream psychologists. In apparent contrast Maccoby and Jacklin believe that males and females are equally intelligent while entertaining the possibility that the two sexes have somewhat different cognitive skills; they suggest a biological origin for such differences. Although the possibility is admissible, I have tried to show both that any such differences are very small and that there is no basis for assuming a priori that these small variations have innate biological origins.

This chapter bears witness to the extensive yet futile attempts to derive biological explanations for alleged sex differences in cognition. Although these efforts all have a certain social wrong-headedness to them, they do not stand or fall on their political implications. Rather, such biological explanations fail because they base themselves on an inaccurate understanding of biology's role in human development. Sperry suggests this when he writes that each person's brain may have more physical individuality than do the person's fingerprints. His statement is radical because it implies that attempts to lump people together according to broad categories such as sex or race are doomed to failure. They both oversimplify biological development and downplay the interactions between an organism and its environment. As a result of doing the research for this book, I arrived at the same conclusion. My feelings come from having thought carefully about the present state of our knowledge about the genetics of behavior, the embryological development of the sexes, and the ways in which hormones act as physiological controllers and evocators in males and females. By coming to understand these aspects of human development, we can see more clearly why simple, unidirectional models of biological control of human behavior misconstrue the facts of biology. We will explore this phenomenon in the next chapter.