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Genetics and the Plasticity of Intelligence

The assumption of fixed intelligence so pervades our culture that, like freeway noise, it recedes from conscious attention to form a life-drama backdrop that is seldom noticed, let alone scrutinized (Hunt, 1961). To test that assumption requires that attention be directed to evidence bearing on the plasticity of intelligence—to whether intelligence can and does change. We will see that intelligence is indeed plastic; even so, genetics is not irrelevant. On the contrary, genetic heritability makes a "significant and substantial" contribution to intelligence (Pederson, Plomin, Nesselroade, & McClearn, 1992, p. 346). The finding is robust and acknowledged by virtually all who have read the relevant research; some call it "indisputable" (Bouchard & McGue, 1981, p. 1058). A more debatable question is: How much of a contribution does heredity make? That is, what is the *heritability* of intelligence? A follow-up question, and one that bears more directly on the polemic of this volume, is whether a genetic contribution to intelligence places a cap on the level of intelligence attainable by an individual.

HERITABILITY AND ITS LIMITATIONS

Heritability, denoted h^2, is defined as the proportion of variance of any trait that can be accounted for by variation in the degree to which genes are shared (Gustafsson & Undheim, 1996; Neisser, 1998). Although the precise value of h^2 for IQ varies from study to study, central tendencies of heritability estimates are around 0.50, with as much error as 0.2 in either direction (see also Bouchard & McGue, 1981). This means that roughly 50% of the variance in measured IQ is associated with genetic variation. This also happens to be the approximate genetic contribution to psychological traits in general (Harris, 1995), including personality traits (Bouchard, 1994), narrower cognitive factors such as verbal and spatial ability (Plomin & DeFries, 1998), and psychopathology (Scarr, 1992). Heritability values are about the same magnitude in accounting for variation in academic achievement (Plomin & DeFries, 1998).

Genetic influences on intelligence are polygenic, involving the expression of many genes in the DNA sequences composing individual genotypes. Empirical data relating IQ to different kinds and degrees of familial relationships are consistent with a polygenic model; that is, the coincidence of heritability values and familial distance is largely a function of the percentage of shared genes.

Recently, geneticists have forayed into exploring the molecular correlates of intelligence. The first single gene associated with high cognitive ability, known as IGF2R (located on the long arm of Chromosome 6), has been identified (Chorney et al., 1998). One particular version of that gene, Allele 5, is about twice as common in high-IQ children as in children of average ability. However, because genetic influences on IQ are strongly polygenic, allele variation in IGF2R can account for only about 2% of the variance in IQ, or about 4 IQ points, in contrasts of high and average IQ samples. The biochemical pathway by which IGF2R exerts its effect on IQ is, at this point, a mystery.

The real workhorses of behavioral geneticists, however, have been studies of twins ("experiments of nature") and adopted children ("experiments of society"; Plomin & DeFries, 1998). Both have shown that the contribution of genotype to variation in IQ is real and substantial (Loehlin, Horn, & Willerman, 1997). Between identical, or monozygotic, twins, the percentage of shared genes is 100%. Across studies, the median IQ correlation for monozygotic (MZ) twins reared together is 0.86; for MZ twins reared apart IQ is correlated 0.76 (Scarr, 1997; see also Bouchard & McGue, 1981). The difference between the two heritability values shows that environmental influences exert an effect, but the still substantial IQ correlation for MZ twins reared apart also speaks to the importance of genetic influences. High heritability values for MZ twins reared apart—in the region of 0.76—are sometimes taken to be evidence for strong genetic determination of IQ. Interpreting this correlation warrants caution, however. It would be a mistake to assume that a heritability value of 0.76 is strictly attributable to heritability. This would be true only if there were a zero correlation between the environments of identical twins reared apart *and* if shared experience prior to separation were irrelevant to IQ. Neither condition is met.

Scientifically, it would be ideal if adoption agencies placed babies at random with families representing the full range of socioeconomic standing. In reality, placement is never random and adopting families tend not to be representative of the population as a whole. Adopted children are more commonly placed with families of higher socioeconomic status (SES), and families with higher SES and IQ are more likely to participate in the types of social science research that document the effects of adoption on cognitive development (Scarr & Weinberg, 1978, 1983). The resulting restriction of range would reduce estimates of environmental (i.e., family) effects, and would therefore magnify the apparent effects of heritability (Neisser et al., 1996).[1] To complicate matters, there are mild associations between natural and adoptive parents in both socioeconomic status and IQ, which has the effect of inflating the correlations of adopted children's IQs with adoptive parents (spuriously supporting environmental effects) and with biological parents (spuriously supporting genetic effects; Scarr & Weinberg, 1983).

Even when twins are separated at birth, they still share some experience, namely the 40 weeks or so that they cohabitate their mother's uterus.[2] Because twins have similar exposure to protein and micronutrients, as well as toxins, those

demonstrably potent environmental factors might later be mistakenly attributed to shared genotype. Even identical twins can differ in their share of placenta-supplied nourishment, which is manifest most obviously in birthweight discrepancies. In fact, in-utero "maternal effects," which are shared by MZ twins reared apart, can account for about 20% of the IQ variance otherwise mistakenly attributed to genes (Devlin, Daniels, & Roeder, 1997). Factoring in these maternal effects reduces the heritability estimate for MZ twins reared apart to around 0.5, which is consistent with other behavior-genetic data. Thus, "nature," although generous to scientists on many counts (e.g., by controlling genotype among "identicals"), does not cooperate fully in providing strictly rigorous "experiments of nature." To completely eliminate genetic/environmental confounds would require not separation at birth, but separation at conception.

Implicative Limitations

The problems of interpreting data from twin and adoption studies do not nullify the important finding that population variation in IQ can be linked to genetic sources. Nonetheless, genetics is not destiny. Even if we take the rough estimate of 50% heritability at face value, the equivalent conclusion is that 50% of IQ variance is attributable to nongenetic influences (Rose, Harris, Christian, & Nance, 1979). Thompson and Plomin (1993) remarked that, in this sense, "genetic research provides solid evidence for the importance of nongenetic factors" (p. 104). Likewise, Scarr and Weinberg (1983) noted that "the major contribution of behavioral genetic studies is to clarify the impact of environmental differences on human development" (p. 266). Counterintuitively, behavioral genetics provides empirical support for the importance of nongenetic factors in shaping intelligence, and has additional theoretical and pragmatic value because it can point to features of the environment that promote the development of intelligence. In the experience of one behavioral geneticist, presenting his data "to public groups outside academia often moves them toward a less hereditarian position" (Goldsmith, 1993, p. 336).

Other data from behavioral genetics supports the importance of experience in shaping intelligence. Consider that the IQs of fraternal (dizygotic) twins are more strongly correlated (0.58) than that of nontwin siblings (0.45), even though their genetic relatedness is the same (Bouchard & McGue, 1981). The cumulative experience of fraternal twins is apparently much more alike than that of nontwin siblings, and this shared experience is reflected in the higher correlation of their IQ scores. Environment effects are also evident in families in which some members are not genetically related, as in the case of adoption. For example, significant IQ correlations are found between siblings who are *not* biologically related (approximately 0.30), and also between parents and adopted children who are unrelated (about 0.20; Bouchard & McGue, 1981; Thompson & Plomin, 1993). A strictly hereditarian model would of course predict zero correlations for each. Differing family experiences also have effects in reducing IQ correlations among

relatives. For example, the IQs of siblings raised apart are correlated about 0.24, which is considerably *less* than the expected value of 0.50 that an extreme hereditarian model would predict.

Even if some consensus is achieved about the relative contributions of genes and the environment to intelligence, the theoretical limitations of these estimates must be recognized. Most important, the relative contributions of genes and the environment to intelligence should *not* be regarded as parameter estimates for the human species for all time. For all its redolence of scientific-sounding precision, h^2 is not like Planck's constant or the speed of light, which are taken to be universal and eternal. Instead, heritability estimates are *descriptive* statistics (Thompson & Plomin, 1993) that characterize a particular sample of people who have definable genetic variability and who reside in definable environments. Given a different distribution of genes (compare the United States and Japan) or environments (compare Switzerland and the Philippines), heritability estimates would shift. For example, if environmental variation increases (imagine a society that becomes more polarized by wealth and educational opportunity), the measured genetic contribution to IQ, that is h^2, would fall (cf., Plomin & DeFries, 1998).

Another limitation of heritability estimates is that they cannot be extrapolated to account for between-group differences (Lewontin, 1970). Group differences in mean IQ, including differences between racial/ethnic groups, certainly exist, but heritability estimates for IQ are immaterial to explaining those differences. As Lewontin (1970) put it, "Between two populations, the concept of heredity of their differences is meaningless" (p. 7). To illustrate, Lewontin asked the reader to imagine taking two handfuls of seed corn (containing plenty of genetic variation) from the same sack, and planting that seed in two types of soil (See Fig. 6.1). The first soil mixture is rich, containing optimal concentrations of all nutrients needed by the corn; the second soil mixture is deficient, containing only half the concentration of nitrates and insufficient zinc. Predictably, the corn in the rich soil mixture will thrive, grow tall, and yield an abundant harvest, but the corn in the impoverished soil will wither. Yet within each soil type, there will be some variation among individual plants in height and other characteristics.

What is the explanation? Because the soil mixtures are strictly controlled, 100% of *within*-group differences must be attributable to genetics. That is, within each soil mixture, heritability is 1.0. What about differences between groups? Genetically, the two handfuls of seed corn do not differ in quality, therefore 100% of *between*-group differences in plant height (and all other characteristics defining health and productivity) are caused by differing environments. If the same corn were planted in a field, genetic variability in the corn and local variation in soil quality might produce a heritability value around 0.5. Yet, we see that it would be a mistake to apply a heritability value of 0.5 to the two experimental conditions in which there are known differences in soil quality. More important, we would be in error to infer that differences in the quality of the corn crop between the two experimental conditions arose from the genetic inferiority of one handful and the superiority of the other.

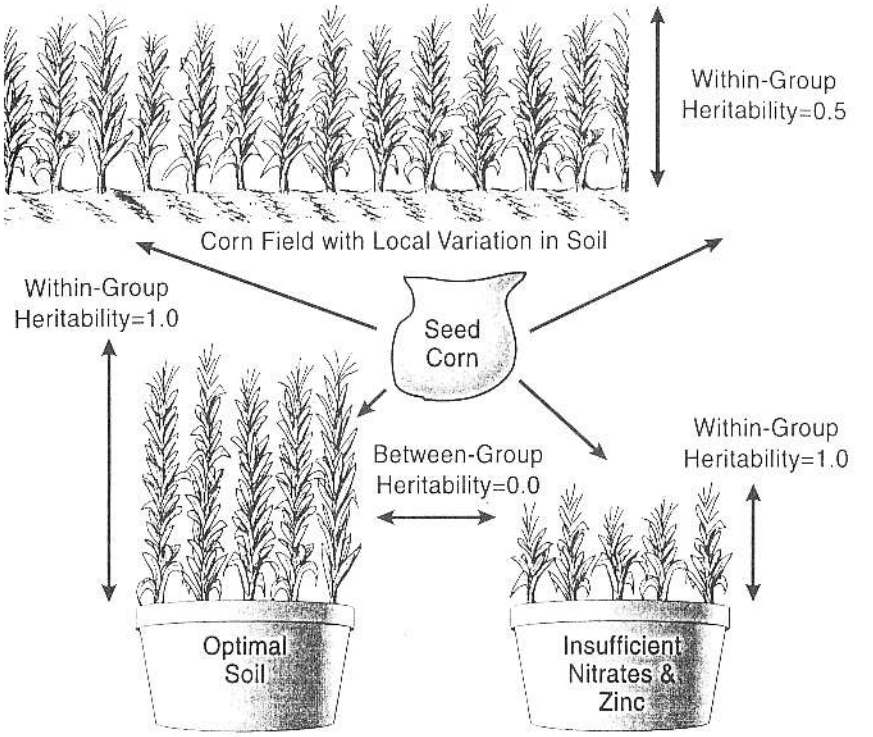


FIG. 6.1. An illustration of the irrelevance of within-group heritability to between-group differences when groups have differing environments.

In *The Bell Curve*, Herrnstein and Murray (1994) co-opted Lewontin's metaphor but planted one hypothetical handful of seed corn in Iowa and the other in the Mojave desert. However, the outcome and the message are the same: The flourishing and the withering "will have nothing to do with genetic differences" (p. 298). To Kaus (1995), "The comeback is obvious: plant the next generation of corn in Iowa. Or water the Mojave" (p. 137). The metaphor applies immediately to the question of why there are large differences in mean IQ between African Americans and Whites, an issue to which the next chapter is devoted. For now, Kamin's (1974) summation removes ambiguity: "To attribute racial differences to genetic factors, granted the overwhelming evidence of cultural-environmental differences between races, is to compound folly with malice" (p. 177).

Merely recognizing the joint influence of genes and the environment on intelligence is not sufficient because this recognition risks the conceptual error of thinking that a heritability of about 0.5 places limitations on how much intelligence can increase. No such limitations exist, at least not by the "fact" of h^2 = approximately 0.5. In fact, even if the heritability of intelligence were 100%,

there is no reason why intelligence could not be modified through environmental factors. Heritability and improvability are logically independent. The point is made vividly in the case of intergenerational increases in height. Angoff (1988) noted that "height has been consistently regarded as an example of a trait with an extremely high heritability index—close to 1.0" (p. 714), and yet in many countries average height has changed dramatically from one generation to the next. In Japan between 1946 and 1982, the heights of young adult males increased on average about 4 inches. The average heights of Europeans and Americans have been increasing at a rate of about 3 centimeters per generation since the mid-1800s; the heights of East Asians have been increasing, since World War II, even faster (Bock & Moore, 1986). These gains are logically independent of the heritability coefficient for height because the coefficient is maintained so long as taller parents continue to have taller children. This is so because, in the computation of correlations, all information on group means and standard deviations is lost; the correlation itself simply reports the degree of correspondence between variables. Even if our descendants were 10-foot-tall giants, the heritability index for height could remain unchanged from current values. For that matter, it could increase—the point is, heritability values are not sensitive to changes in the absolute magnitude of any trait.

The implicit principle—that heritability and modifiability operate independently—applies with equal force to intelligence as to stature. Referring to height, Angoff (1988) concluded that "if a trait with this degree of heritability is so changeable, then other traits, like intelligence, which are acknowledged to have lower heritability coefficients, may also be changeable" (p. 714). Angoff's point, although crucial, has been lost even on some specialists in the field. For example, Herrnstein and Murray (1994) spoke of "the limits that heritability puts on the ability to manipulate intelligence" (p. 109). Recognizing that misconceptions about intelligence are widespread, Scarr noted that "the most common misunderstanding of the concept of heritability relates to the myth of fixed intelligence" (1981b, p. 73), and lamented that "the myth of heritability limiting malleability seems to die hard" (1981a, p. 53). Other behavioral geneticists have likewise decried the mistaken idea that if a trait has a genetic component it cannot be influenced by the environment (Thompson & Plomin, 1993). Binet (1909) himself spoke against the "brutal pessimism" of seeing intelligence as a prescribed and intractable quantity (p. 54). We now know that the idea is not only pessimistic, it is unscientific.

We are correct, of course, to regard genes as setting limits on the range of phenotypic variation. Paul Bunyan cannot exist because biomechanical considerations would make such a design unworkable, and more realistic ranges for height are encoded by DNA gene frequencies and combinations. Phenotypic limitations exist, but who knows for sure what those limitations are? What were once dictatorial holds of DNA on phenotype have been abrogated through technologies. Even the expression of monogenic traits, as for phenylketonuria

(PKU), can be modified by environmental intervention (Lewontin, 1970; Plomin & DeFries, 1998). In the case of PKU, exposure to the amino acid phenylalanine can be deadly, but with an appropriate diet the affected person can lead a normal life. Therefore, although genes impose theoretical limits on phenotype, including, presumably, upper bounds on intelligence (Hebb, 1949), it is impossible to know a priori what those limits are (Hunt, 1961). As geneticists have long recognized, knowing the "range of potentialities of a human genotype" would require that a genotype be exposed not only to all existing environments, but to "all the lives possible to human beings" (Sinnott, Dunn, & Dobzhansky, 1958, p. 24). Because this condition has never been met, nor can be, no one can foresee the limits of human intelligence (Lewontin, 1970). It is possible that the human race can become far more intelligent than it is at present (Perkins, 1995).

Conceptual Limitations

Influences on cognitive development do not cleave into genetic and environmental factors as neatly as we might suppose (Keating, 1996). Even when genes play a role in behavior, the actualization of that role might depend completely on experience. For example, a child's rate of vocabulary acquisition has a genetic component, even though every word is learned through experience (Neisser et al., 1996). This illustrates a general principle well known to biologists, which is that the environment affects gene expression. The reverse is also true: Genes can shape the environment. Genetic factors can lead to qualities of behavior to which the environment responds, producing *reactive* (or evocative) covariance between genes and the environment (Scarr, 1992; Wachs, 1996). Physical, mental, and psychological characteristics, some of which have a genetic origin, can shape the psychosocial and physical environment, which then echoes back to shape internal characteristics (Joffe, 1982). The net effect is a reverberating codetermination of genetic and environmental influences. Think of how sensitive parents respond to a precocious child. Competent parents calibrate interactions with their child according to that child's needs and abilities, and parents' responsiveness can have reciprocal effects in advancing the development of the child (Ho, 1987). Such processes can form either positive feedback loops, which reinforce and extend interindividual differences, or negative feedback loops, which reduce differences (Harris, 1995).

Gene-environment covariance can also be *active*, as when a person's genotype leads to the pursuit of certain qualities of experience through the selection or construction of environments (Greenough & Black, 1992; Wachs, 1996). That is, genes can cause children to "create their own environments" (Bouchard, 1994, p. 1701; Scarr, 1992). The importance of idiosyncratic experience pathways is suggested by the fact that, for many traits, most of the variance attributable to the environment is actually associated with *nonshared* aspects of experience, whose effect is to make members of the same family different from one another (Scarr,

1992). This mechanism might also explain why the genetic contribution to intelligence appears to *increase* through the life span. A growing genetic contribution is consistent with the idea that children have relatively little say in the structure of their day-to-day experience, whereas older adolescents and adults are "freer to seek their own niches" (Scarr & Weinberg, 1983, p. 260). Presumably, genes have more freedom for expression because adolescents and adults have options that are not available to young children.[3]

However, the volition of even young children can result in the construction of specialized experience. Winner (1996) cited the case of 4-year-old Jacob who, upon hearing heavy metal music for the first time, begged his parents to let him play an electric guitar. After listening to Jacob's incessant pleading for 2 years, his parents relented, bought him a guitar, and found a music teacher. Winner (1996) recounted what followed:

> At his first lesson, scheduled for 30-minutes, Jacob refused to leave. Whereas most children are relieved that a lesson is over, Jacob did not want it to end. After his second lesson, his teacher was certain that Jacob was a prodigy. He would play back just about anything by ear, he could master complex music seemingly without effort, and he could improvise in a musical manner. Once while on an outing with his father, Jacob passed a group of street musicians. He asked to try their electric guitar and astonished bystanders, who were heard joking that he must be the reincarnation of Jimi Hendrix. (p. 285)

We do not know for sure whether Jacob's obsession with heavy metal guitar music was genetic in origin, but given his parents' reluctance to pursue this path (they felt that this was not a "childlike kind of music"; Winner, 1996, p. 285), a "nurture" explanation is hard to accept.[4] The example of Jacob illustrates how active gene-environment covariance might operate—by genes producing experience through the person's own agency. It also injects a dose of skepticism into claims that the environment is prepotent.

How are the effects of active gene-environment covariance parceled into nature and nurture? The answer is, not easily (Neisser, 1998). Active covariance between genes and environment is not clearly nature *or* nurture, but is more accurately described as an example of reciprocal determinism in which each can affect the other, and in which the relative influence of genes and experience varies depending on the trait, behavior, and situation (Bandura, 1986). The importance of active choices and niche building might extend far beyond their intrusion into gene-environment covariation. Fine-textured, idiosyncratic microexperience might be responsible for that much larger "bucket" of individual variation that cannot be accounted for by either genotype or commonalities of experience between persons (i.e., that troublesome slice of the variance pie that statisticians like to call "error").

Active covariation finds a parallel in Hayes's (1962) drive theory of intelligence. Hayes (1962) proposed that "intelligence is acquired by learning, and [that] inherited motivational makeup influences the kind and amount of learning that occurs" (p. 302). According to Hayes, experience-producing drives originate from genotype but are actualized only through experience. This hybrid mechanism represents an annoying exception to tidy dichotomous models that segregate genetic and environmental effects. By Hayes' account, genes can lead to differences in experience that are mediated by the learner's own experience-seeking behavior. So what is causal? In one sense it is genetics, because genes produce differences in experience-seeking behavior. But intelligence is enriched *only* by means of consequent experience, and must also be limited by the range of experiences that are available. The complicating element inserted by Hayes is that the individual can select and shape experience. Environments don't just "happen" (Wachs, 1996; see also Sternberg, 1985a).

It gets more complicated. Not only can genes affect the environment, but the environment can also affect gene activity. Genes depend on appropriate environments, or rather a hierarchy of environments, for their normal expression, but they also respond to specific events and experiences to produce idiosyncratic development (Greenough & Black, 1992). At a molecular level, the immediate environment of each DNA strand determines which of tens of thousands of genes turn on within a cell nucleus. The nucleus is, in turn, enveloped by cytoplasm, and the cytoplasm by a cell membrane (Figure 6.2). Each cell is affected by the paracrine hormones secreted by adjacent cells, and by the endocrine environment of the organism as a whole. Beyond the skin interface is the "outside," which is itself composed of concentric shells of physical and social contexts. Each hierarchically nested environment can exert effects on adjacent environments, and these effects can cascade through several levels (Weiss, 1959). More to the point, the experience of the organism can regulate the intensity of gene expression, such as when exposure to light induces protein synthesis in the visual system (Greenough & Black, 1992).[5] In neuroscience research, the level and location of mRNA expression by the gene *c-fos* is used to map which brain structures are activated by different types of learning (Gall, Hess, & Lynch, 1998). When gene expression is understood in these terms, we might see the genotype itself as expressing behavior—some of which is dependent on experience, some of which is not. Does that raise the nature-nurture question for the behavior of genes?

Multicausality, reciprocal causality, and unresolved conundrums reinforce the message that the nature-nurture question, so glibly posed—"as if the conjunction were 'or'" (Scarr & Weinberg, 1983, p. 260)—is actually the wrong question because it tacitly accepts simple-minded and misleading assumptions. Some geneticists have even called the nature-nurture question "meaningless" (Sinnott et al., 1958, p. 19). To ask, "Is it nature or nurture?" or even "How much of each?" glosses complexity by smoothing over intricate and powerful interactions of causal forces that cannot be dismissed as mere hair-splitting technicalities.

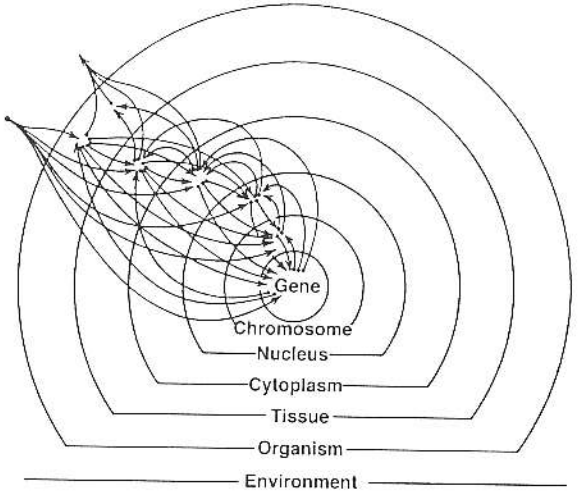


FIG. 6.2. The interparticipation and mutual regulation of multiple levels of biological, cognitive, and sociocultural systems in the developing person. From "Cellular Dynamics," by Paul Weiss, 1959, *Reviews of Modern Physics, 11*(1), p. 18. Copyright 1959 by the American Physical Society. Reprinted with permission.

INTRA-INDIVIDUAL PLASTICITY

The idea that cognitive abilities are products of experience was probably articulated best by Ferguson (1954). Ferguson argued that abilities represent overlearned skills that reach asymptotic limits, and that those asymptotes will vary from culture to culture. This is so because cultures differ in their demand for and valuation of various cognitive abilities, as well as in the provisions they afford for their development. One vivid example is Gladwin's (1970) account of the rigorous training and high regard given to open-ocean navigators in the Micronesian atoll of Puluwat. Similarly, Hungarians have historically maintained a deep commitment to the universal development of musical proficiency. Within cultures, the developed abilities of an individual should be regarded not as *limitations*, but as stable plateaus whose elevation is a function of environmental demands and opportunities (Kohn & Schooler, 1973). This view of cognitive abilities, as learned skills that are shaped by culture, applies equally to intelligence as to any other psychometrically defined ability. The same principle, expressed by Lohman (1993), is that "intelligence tests, like achievement tests, measure *developed* abilities, not innate capacity and potential" (p. 13). Humphreys (1989) likewise declared that "general intelligence is itself a developed ability" (p. 198). Cognitive abilities, including intelligence, are plastic.

The plasticity of intelligence is not a mere theoretical possibility, but is an established fact. This is clearest in the case of absolute levels of intelligence. As perhaps obvious proof, consider (as Piaget did) the average differences in cognitive ability among children at ages 2, 7, and 12. In all normal children, cognitive ability rises rapidly with maturation and enculturation (Boring, 1923; Carroll, 1997; Sternberg, 1990a), a trend long appreciated by developmental psychologists and sometimes described by *stages* (Inhelder & Piaget, 1958), and indexed by psychometrists as *mental age* (Cronbach, 1984). The steep rise in absolute levels of intelligence, measurable as raw scores on ability tests, necessitates the calibration of norms to age levels. Typically, mental age climbs steadily through early adulthood at least, and one way of interpreting IQ is the steepness of this curve (Carroll, 1997).

Norm-based measures of intelligence, indexed by IQ scores, also change over time. For example, IQ drift is common during childhood and adolescence (Hunt, 1961). Within-person correlations of IQ scores drop steadily from age 2 to age 15 (Humphreys, 1989). This instability, according to Humphreys (1989), "is a monotonic function of the amount of time between the original score and the score at retest" (p. 200). As the period of time between tests increases, the relationship between successive IQ scores becomes weaker. Yet, paradoxically, the heritability of IQ seems to increase as a function of age (Pederson et al., 1992). This does not necessarily reduce the importance of the environment, however, because the apparent increase in heritability with age may be driven by genetically influenced tendencies to seek certain kinds of experience; and, as one grows older, there is typically greater discretion to choose among life paths that vary in their experiential quality. The opportunity to pursue high-quality experience then becomes crucial.

IQ "instability" has been observed not only from year to year, but also from hour to hour. There is evidence, for example, that crystallized, fluid, and other abilities exhibit diurnal fluctuations with characteristic patterns (Cattell, 1987). Studies of circadian and sleep-wake rhythms have revealed that cognitive performance oscillates according to the time of day, although the form of that oscillation depends on the specific type of cognitive performance measured (Folkard & Monk, 1985). For example, many simple reasoning tasks yield performance curves that parallel the inverted-U pattern of general physiological "arousal," as indexed by body temperature. Performance on low-demand tasks peaks at midday, but as tasks increase in working memory load, optimal performance shifts to earlier in the day. For tasks highest in working memory demand, the curve turns upside down—performance is highest in the early morning hours, drops off by midday, and surges again in the evening hours (Folkard & Monk, 1985). These fluctuations appear to reflect both external events, such as food consumption, as well as endogenous biochemical cycles (Horn, 1967). In psychometric models, these temporal fluctuations are embedded in the estimated

unreliability of mental tests; in reality, they exhibit regularities that are at least partially understood.

Although IQ scores can change from year to year, they tend to show appreciable stability. However, the interpretation of that stability is unclear. Initial IQ differences may lead to separate experiential paths that reinforce or even magnify the initial cognitive differences. This is so because environments can be responsive to differences in ability between people—consider, again, the sensitive parent or the talented teacher. IQ stability might therefore reflect, in part, the effects of a responsive environment that preserves the initial rank orders of IQ and therefore limits IQ mobility (Lewontin, 1970). To the degree that such effects come into play, IQ stability should not be taken as evidence for the controlling influence of genes over experience. In other words, the inference from stability to unchangeability is logically flawed. As Lewontin (1970) expresses this point: "To say that children do not change their IQ is not the same as saying they cannot" (p. 4).

The plasticity of intelligence is lifelong. Cognitive development continues into adulthood and extends through the life span (Alexander & Langer, 1990). Separating the age trends of crystallized and fluid intelligence leads to a more precise picture of how intelligence changes over time (Dittmann-Kohli & Baltes, 1990; see Figure 6.3). Crystallized intelligence (CI) continues to grow to at least the age of 50, and perhaps longer. Fluid intelligence (FI), however, usually reaches a plateau between the ages of 16 and 30, and then declines thereafter at a rate of about 0.04 standard deviations per year (Cattell, 1987; Hunt, 1995). Horn (1967, p. 30) cheerily described this trade-off as the substitution of "wisdom for brilliance." A composite intelligence represented by the FI + CI curve presents a hopeful picture about the way cognitive power ebbs and flows over the life span.

What is unclear, and controversial, is whether the decline of fluid intelligence is inevitable. The explanation for a decline in fluid ability may rest simply with the notion that there is less need for adaptation to new situations as one ages. On the other hand, the explanation may be biological—the loss of cognitive powers may be a consequence of accumulated neuron loss or degeneration, attributable in part to injury or exposure to toxins. Cattell (1987) noted that brain mass typically declines by about 10% between the ages of 30 and 90. A loss of fluid ability may not be debilitating, however, if an older person can exploit his or her accumulated experience in the form of knowledge, just as in an expert-novice transition the relative importance of cognitive resources shifts toward a greater reliance on domain knowledge. Researchers who study the question of why fluid ability declines, regardless of their position, *do* agree on one thing, however: Neither fluid nor crystallized intelligence is fixed, but each can (and does) shift up or down over the life course, contingent largely on individual interests, allocation of time, and opportunity (Baltes & Schaie, 1976; Cattell, 1987; Horn, 1967; Sternberg, 1990a; Vernon, 1948). As life experience varies from over time, IQ can rise or fall, sometimes radically (Dittmann-Kohli & Baltes, 1990; Hunt, 1961).

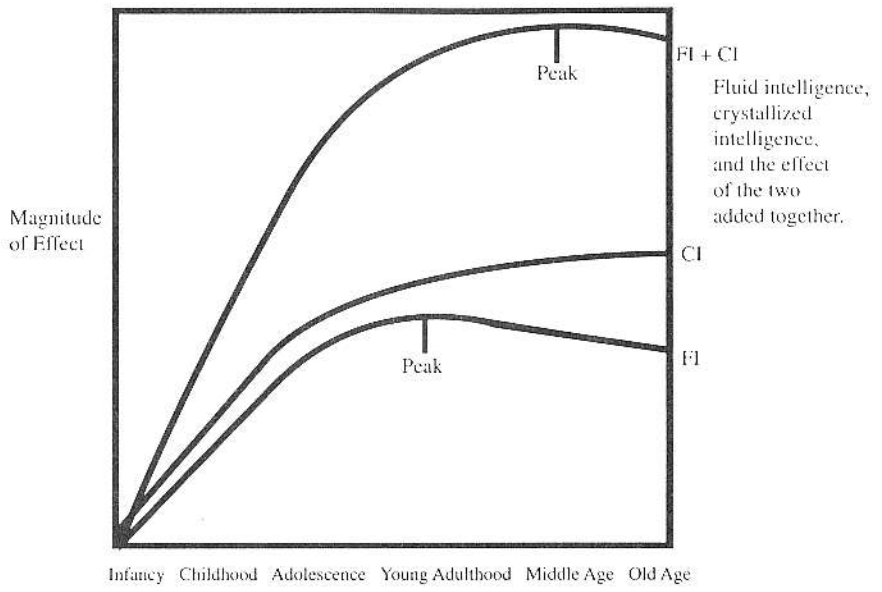


FIG. 6.3. Change trends for fluid and crystallized intelligence, and their combination, over the life span. From "Intelligence—Why It Grows, Why It Declines, " by J. L. Horn, 1967, *Trans-Action, 5,* November, p. 31. Reprinted by permission of Transaction Publishers. Copyright ©1967 by Transaction Publishers; all rights reserved.

Early in the 21st century, the American workforce will experience a significant shift in age distribution: Older workers will have much greater representation in the workforce than they do at present. Given this age redistribution, Hunt (1995) worried that the life-span trendlines for fluid and crystallized intelligence do not bode well for American economic competitiveness. Age-related trends for fluid and crystallized intelligence imply that the distribution of cognitive abilities in the American workforce will shift such that crystallized intelligence (i.e., knowledge and expertise) will be amply supplied, but that the flexible problem-solving ability denoted by fluid intelligence may, per capita worker, be less available (Hunt, 1995). To be sure, any absolute changes in fluid and crystallized intelligence would be small, but the fact that they would apply widely across the workforce means that their summed effect could be substantial. According to Hunt (1995), an age-related shift in the composition of cognitive abilities could not come at a worse time because the global economy and the technologies that drive it make greater demands than ever on the ability to solve new problems and grasp new ideas.

INTERGENERATIONAL PLASTICITY

The Flynn Effect

Another form of IQ instability is its plasticity between generations. Intergenerational plasticity is strikingly demonstrated in the worldwide, decades-long trend of rising IQs, sometimes known as the *Flynn effect* (Flynn, 1987, 1998). This phenomenon recognizes that IQs have been rising for most of the 20th century in every country for which pertinent data are available. So robust is the trend that James Flynn (1998) referred to the trans-national secular IQ gains, his namesake, as a "brute phenomenon" (p. 25). "Somewhere out there," said Flynn (1998, p. 53), "environmental variables of enormous potency are creating IQ differences." Figure 6.4 illustrates the effect as gains in Wechsler-Binet IQ for the U.S. White population during the period 1918 to 1995.

Flynn (1987) has estimated that during the 20th century there was an IQ gain per generation (30 years) of about 15 points—a full standard deviation. In a later paper, Flynn (1996) contended that an intergenerational IQ gain of about a standard deviation has been found, without exception, in the 20 industrialized nations for which he had obtained data. In Britain, these IQ gains have been accumulating for at least a century, and the trend's starting point seems to coincide approximately with the advent of industrialization (Flynn, 1998). A recent restandardization of the Wechsler tests show a further gain in mean IQ since 1978 (Jencks & Phillips, 1998c). There is no indication that the trend is leveling off; in some countries, such as the Netherlands, the *rate* of IQ gain has been increasing (Flynn, 1998).

Rising IQ trends are not mere artifacts of greater familiarity with tests and test taking (Lynn, 1990; Teasdale & Owen, 1987). For one thing, the intergenerational

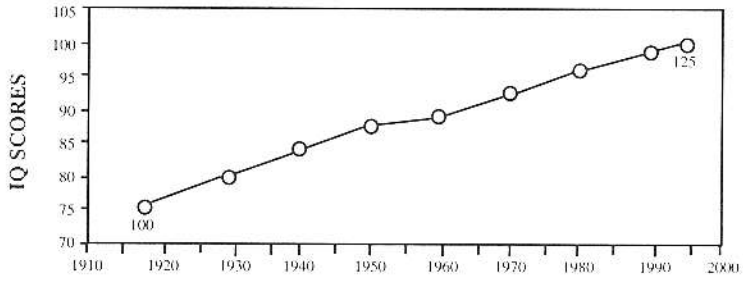


FIG. 6.4. An example of the Flynn effect: Gains in Wechsler-Binet IQ for the U.S. White population. From "Get Smart, Take a Test," by J. Horgan, 1995, *Scientific American, 273*(5), p. 14. Copyright 1995 by Dimitry Schildlovsky. Adapted with permission.

escalation of IQ actually pre-dates the widespread use of cognitive tests and has persisted into an era when IQ testing has become less common. Also, the gains are simply too large to be attributed to test sophistication. Repeated exposure to IQ tests can produce gains of about 5 or 6 points, but nothing like the IQ gains in Britain, which are on the order of 30 points (Flynn, 1998). Indeed, intergenerational IQ gains are so massive that they are unlikely to be explained by any single factor.

The Flynn effect is demonstrable across a broad spectrum of cognitive abilities. Lynn (1990) pointed out that "increases have been found in all major components of intelligence, including reasoning, verbal comprehension, and visuo-spatial abilities" (p. 280). However, the magnitude of IQ gains depends substantially on the cognitive ability factor assessed. A broad distinction can be made here between gains in fluid intelligence and gains in crystallized intelligence. IQ gains have been greater on tests of decontextualized problem solving (or fluid intelligence), such as measured by Raven's Matrices, than on tests corresponding more closely to school subjects (or crystallized intelligence). In the Netherlands, Raven-based IQ has leaped about 21 points in 30 years, far higher than gains on tests that tap domain knowledge (Neisser, 1997). Broad measures of IQ, including the Stanford-Binet and Wechsler Adult Intelligence Scale (WAIS) batteries, have evinced smaller although equally consistent effects on the order of about 3 points per decade (Neisser, 1998). Because intergenerational IQ gains are more pronounced on measures of fluid intelligence than of crystallized intelligence, the Flynn effect cannot be explained by saying that later generations simply possess more knowledge than their forebears.

One consequence of rising IQ is that tests of cognitive ability been "recentered" periodically to reestablish their means at 100. The periodic renorming has tended to conceal the upward trend in raw test scores, producing a fictitious constancy of meaning of IQ across time (Sowell, 1995). Therefore, although IQ = 100 has been reasserted and redefined with each new generation—what *was* average now is not. IQs have increased—that much is known. A wide-scale increase in measured IQ in the 20th century is now beyond dispute (Neisser, 1997, 1998). But has *intelligence* also increased? Flynn (1987) proposed that "those who wish to identify the problem-solving ability IQ tests measure with intelligence must argue that the current generation is radically more intelligent than the last" (pp. 184-185).

Flynn himself, however, did not believe this. The problem for Flynn was what a large rise in intelligence *implies*. Flynn considered differences between U.S. populations in 1918 and 1995, which are separated not only by time but also by an IQ gap of 25 points. An average person (IQ = 100) in 1918, if transported to 1995, would be very much below average (IQ = 75); in fact, that person would be borderline retarded. Flynn (1998) asked, "Does that mean that during World War I about half of White Americans lacked the capacity to understand the basic rules of baseball?" (p. 36). To Flynn, the suggestion is absurd, and thus a large IQ gain cannot really indicate an increase in intelligence. But is a substantial gain in intelligence really so farfetched? Although we do not have data on WWI soldiers'

understanding of baseball, Humphreys (1989) argued that there were discernible differences between WWI soldiers and WWII soldiers in the speed with which they were able to master their duties, namely that the latter soldiers learned much more quickly. In chess competition, the average age of world-class players dropped steadily in the 20th century, a trend that Howard (1999) took as "real-world" evidence that intelligence was rising. At the same time, daily life became more complex (Schooler, 1984, 1998). Granat and Granat (1978) demonstrated that people with low IQ scores found social adjustment increasingly problematic. Some who would not have been called retarded in the past exhibited functional deficits that justified the label. More to the point: It was not genetics that differentiated the 1995 adult from his or her 1918 counterpart, but that each lived in different ecologies with different demands and opportunities (Greenfield, 1998).

Flynn also considered the reverse situation. If a typical person (IQ = 100) were transported to 1918, that person would be considerably above average (IQ = 125). The inference is that if intelligence really has increased, the world holds a lot more smart people now than it did back then. So, asked Flynn, where's all this brilliance? If today's average person is so bright by 1918 standards, do we see evidence for this? Flynn did not think so. As contrary evidence, he pointed to the fact that in the Netherlands there are fewer patents issued now than in the past. This particular example, however, is patently flawed. It is obvious that patent filing is a competitive enterprise, and the nature of the competition changes over time. During the 20th century, invention moved from the shed to the laboratory, where welding was more typically done with a laser than with a torch. The inventor of today competes with a population that is more highly trained and technologically equipped. Patent laws have changed in the interim. Schooler (1998) pointed out that unless all these potentially relevant factors are held constant, which is probably impossible, a change in the number of patents issued is not a good index of intellectual productivity. Even without such controls, is it really so unreasonable to believe that rising levels of intelligence have been manifest as escalations of creative productivity? The incessant proliferation of technologies, ideas, and art forms of all kinds suggests that the world is rife with intelligence and creative production, and of course knowledge itself has mushroomed.

No doubt the meaning of the Flynn effect will continue to be debated. However, the *cause* of rising IQs is also at issue. As noted earlier, explanations based on shifting gene frequencies can be quickly discounted because there has not been enough time for natural selection to produce such a large effect and, thankfully, the "eugenic" agenda of selective reproduction has for the most part been relegated to dystopian fiction.[6] Moreover, population studies have actually confirmed the negative correlations between IQ and fertility so dreaded by eugenicists, but without the feared IQ decline.[7] The explanation for the Flynn effect is not genetic, but environmental. Referring to the secular gains in IQ, Neisser (1998, p. 15) remarked that "however one may choose to interpret it, . . . the environment matters!" But which aspects of the environment are responsible? Several hypotheses have been

advanced, including improvements in nutrition, increases in cognitive stimulation, urbanization, proliferation of information technologies, and the eradication or reduction of childhood diseases.

It is likely that the Flynn effect has arisen not from a single cause, but from a combination of influences. Indeed, IQ gains in different countries may have different patterns of underlying causes (Flynn, 1998). Lynn (1990) favored a nutritional explanation, and showed that in prior decades there has been widespread suboptimal nutrition, manifest as deficiencies in vitamins, minerals, essential fatty acids, and protein, and that improved nutrition has been experimentally linked to increases in IQ (however, see Flynn, 1998, for counterevidence). Widespread nutritional improvement may have had effects on IQ, brain weight, and body size; Lynn demonstrated that the magnitude of IQ gains over the past 50 years corresponds roughly to increases in average height and head circumference—all are on the order of one standard deviation (Miller & Corsellis, 1977). Moreover, better nutrition has been shown to have stronger effects on visuospatial abilities than on verbal educational abilities, a pattern that coincides with the Flynn effect pattern of larger gains on tests of nonverbal than verbal ability (Benton & Roberts, 1988).

Although improved nutrition may have contributed to rising IQs, nutrition alone is unlikely to account for the phenomenon. The jump in cognitive power indexed by rising IQs can be thought of as a response to the demands and opportunities of living in a complex world—that is, "complexity of life" has produced "complexity of mind" (Neisser et al., 1996, p. 90; Schooler, 1998). Environmental complexity has been associated with enhanced cognitive capabilities across the life span, and in non-human species enriched environments are known to produce more complex brain structures (Schooler, 1984). In human societies, environmental complexity is multidimensional. Greenfield (1998) argued cogently that rising IQ scores are the product of four interlocking factors of societal transformation: technology, urbanization, formal education, and nutrition. All four can be seen as reflecting the demands and affordances of the cultural change that some call modernization, whose onset and pace varies between countries and by locale within countries.

To illustrate, Greenfield cited Wheeler's (1970/1942) study of Tennessee mountain children, and in particular his documentation of the upward trend of IQ scores during the period 1930 to 1940. During that 10-year span, children living in rural eastern Tennessee displayed an 11-point increase in IQ. Also during that decade, the region experienced a number of social changes that correspond to Greenfield's interlocking factors of modernization. Most important, perhaps, were improvements to the local road system, because this renewed infrastructure had secondary, cascade effects. Better roads, for example, permitted visits by a circulating library of 14,000 volumes. There were also fewer one-room schoolhouses as students were provided with transportation to larger consolidated

schools that were better equipped and better supplied with textbooks. Hot lunches were introduced in the larger schools, ostensibly improving the dependability of good nutrition. School enrollment increased by 17%, and school attendance increased by 32%, partly as a result of new incentives for student attendance. During the same decade, teacher training requirements were raised to a minimum of 4 years of college education. Finally, because of improvements to the road system, many residents had easier access to industrial employment and so could supplement or replace their agricultural livelihoods.

Presumably as a combined product of these improvements, the characteristics of the typical student in each grade changed substantially (Fig. 6.5). In 1930 (dotted lines), chronological age (C.A.) and mental age (M.A.) were quite discrepant. By 1940 (solid lines), C.A. and M.A. had converged substantially, with mental age increasing by 9 months, and chronological age decreasing by 8 months, on average, at each grade level. The convergence meant that the difference between M.A. and

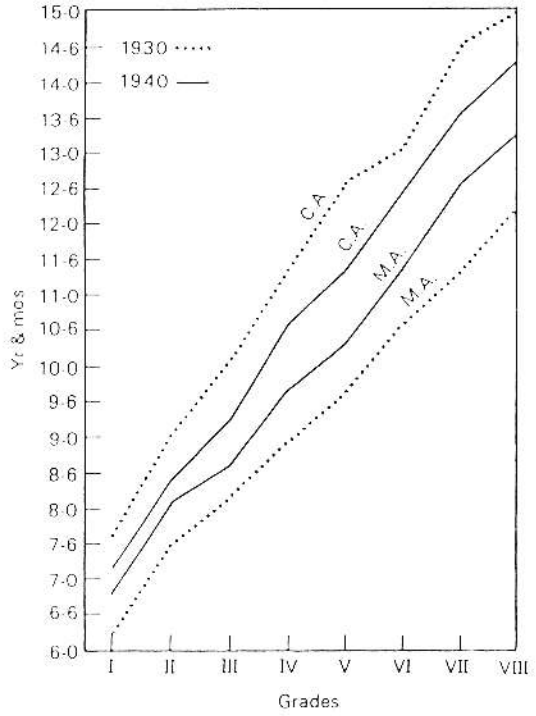


FIG. 6.5. Convergence of mental age and chronological age among Tennessee mountain children. From "A Comparative Study of the Intelligence of East Tennessee Mountain Children," by L. R. Wheeler, May 1942, *The Journal of Educational Psychology, 33*(5), p. 326. Public domain.

C.A. had shrunk by two thirds and IQs were therefore higher. This translated to an increase in median IQ from 82 (classified "dull") to 93 ("normal"). To Wheeler (1970/1942) these findings demonstrated that "intelligence, as measured by these tests, may be improved with an improvement in educational and general environmental conditions" (p. 132).

A more contemporary aspect of modernization highlighted by Greenfield (1998) is the massive exposure to electronic technologies that involve visuospatial displays of information. Visual media—including television, video, film, and computer graphics—are plausible agents of the wide-scale cognitive enhancement of nonverbal abilities identified with the Flynn effect. Visual media may be more complex than in the past (Neisser, 1997); many require the viewer to adapt rapidly to shifting spatial perspectives, exercising the viewer's ability to hold and transform three-dimensional representations. Also, computer-based instructional technologies sometimes present externalized representations, including mental model analogs, that can be internalized and manipulated by the learner (Greenfield, 1998; White, 1993).

Yet another possible explanation for the rightward shift of IQ is the greater availability and intensity of formal education—the "schooling effect" hypothesis (Cahan & Cohen, 1989). There now exists a large accumulation of data, reviewed in the next chapter, showing that schooling does have an effect on IQ. This effect is supported indirectly by the best-documented instance in which *no* increases in IQ were found over roughly a generation. Virtually no differences in IQ were detected among Scottish 11-year-olds between 1932 and 1947, a constancy that the investigators attributed to similar levels and quality of education between the two cohorts (Loehlin, Lindzey, & Spuhler, 1975). However, these same authors also found that, in other times and locations, improvements and expansions of education were associated with a rise in IQ of as much as 15 points. Other nonschool factors also come into play. In the Netherlands, for example, schooling effects accounted for only a small fraction of variance associated with IQ gains (Flynn, 1998), and thus schooling should be considered only part of the explanation for rising IQs.

Although the rising IQ trend is a worldwide phenomenon, it is possible that there are substantial differences among nations in the slope of that trend. There are small-sample data showing, for example, that the rate of IQ gain among Japanese schoolchildren may be double that of their White American counterparts. Hunt (1995) already broached the possibility that the gentrification of the American workforce may result in an insufficient "supply" of fluid intelligence—a small shift statistically, but possibly one with large economic consequences. International variation in IQ growth rates might alter the vocabulary of national debates on the interlocking factors of education, human capital, economic competitiveness, and national security. In one form or another, these factors have fueled debate or shaped policy for some time—at least since 1957, when the launch of Sputnik triggered a massive federal investment in revitalizing education, or the comparable

jolt of 1973 when the OPEC oil embargo announced the death of American economic self-sufficiency.

Intergenerational IQ Shifts Among Immigrants

The worldwide, intergenerational rise in IQ known as the Flynn effect is remarkable in its own right. Whatever its causes, its existence is proof that absolute levels of intelligence are not genetically prescribed (Neisser, 1998; Sowell, 1995). However, in certain subgroups, intergenerational changes in IQ have been observed before the Flynn effect was discovered. Sowell (1995) cited, for example, the case of Jewish immigrants to the U.S. following World War I. Their mental test scores were so low as to prompt Carl Brigham, creator of the Scholastic Aptitude Test, to remark that the results "disprove the belief that the Jew is highly intelligent" (Sowell, 1995, p. 74). However, within a decade, Sowell noted, Jews in the United States were scoring above the national average. Similar trends over generations and immigrant status can be cited for other ethnic groups, including Hungarians, Italians, Russians, and Poles (Gould, 1981; Sowell, 1995). Unfortunately, American immigration policy has at times been influenced by bigotry and propaganda surrounding the alleged preponderance of "defectives" among certain ethnic groups. Enactment of the Immigration Restriction Act of 1924 imposed severe quotas on immigration from nations of "inferior stock," largely southern and eastern Europeans (Gould, 1981, p. 232). Such dark moments in U.S. history should make us hesitate before pronouncing judgment on the intellectual qualities or capabilities of any group. The following chapter returns to this theme.

CONCLUSION

This chapter rests on two arguments. First, although genetics plays a role in the development of intelligence, its constraints on intelligence are far less than is typically believed. Second, the plasticity of intelligence is readily demonstrable, both within individuals and across generations. These two principles converge in the Flynn effect—the phenomenon of global IQ gains during the 20th century. Rising IQs around the world demonstrate that the heritability of IQ imposes no logical constraints on the actual values of IQ. The Flynn effect is vivid evidence of the principle that heritability does not limit malleability. Intelligence is plastic not only between generations, but also within individuals over time—both in absolute terms (as mental age) and in comparative terms (as IQ, fluid, and crystallized intelligence). Although genetics must ultimately place phenotypic limits on organisms in intelligence as in all other traits, no one yet knows what those limits are.

NOTES

1. Problems of representativeness are characteristic of behavior-genetic studies generally, not just studies involving adoption. Samples have been predominantly White (raising questions about generalizability) and restricted in SES range (reducing estimates of environmental effects; Waldman, 1997).

2. It is possible to estimate the effects of "correlated environments" that include shared prenatal experience, independently of "shared rearing environments" (Pederson et al., 1992). However, these effects are usually estimated only after variance attributed to genetics is removed—variation that might be confounded with prenatal experience (e.g., in the IQ correlation of MZ twins reared apart). In any case, estimates of the effects of correlated environments (excluding shared family experience) are rarely computed.

3. In a theory of gene-to-environment effects, Scarr (1992) recognized a third type of genetic influence on experience. *Passive* effects are those that are obtained by the fact that biological parents provide genes and also structure the home environment, ensuring that the two are positively correlated.

4. In fact, one could ask if *nurture* is even the right word to use, because nurture implies the intentionality of others but dismisses the agency of the subject (Bidell & Fischer, 1997).

5. Another example is the adaptation of eye shape to visual experience. Myopia, or nearsightedness, is much more common in literate than in nonliterate populations (Wallman, 1994). For example, incidence of myopia among students in Hong Kong and Taiwan was found to be between 70% and 80%, compared to 20% to 30% in rural areas of China. Among Greenland Inuits, the incidence of myopia increased tenfold in 32 years. Myopia is caused by eyes that are structurally too long to focus distant images. Eye length, in turn, is influenced by physiological events that are at least partly governed by gene activity. These genetic events appear to be responsive to how frequently the eyes are focused at the distance of a page (among readers) or at infinity (among those whose activities are largely outdoors).

6. One notorious exception was the Nazi breeding campaign called the Lebensborn ("Fountain of Life") project (Hammer, 2000). Under the direction of SS chief Heinrich Himmler, the project urged blond, blue-eyed women to mate with tall, fit SS officers to produce a "master race." Between 1935 and 1945, 11,000 children were born under the auspices of the Lebensborn project (Williams, 2000).

7. Shockley's (1972, pp. 307-306) fear of "down-breeding" among low-IQ Americans led him to make the outrageous proposal of providing incentives for voluntary sterilization, with a $1000 "bonus" delivered for each IQ point below 100.

7

The Race Question

Unequal achievement among population groups is a source of unrelenting frustration to all who care about education and social equity. Historically, Black-White differences have dominated the discussion of unequal achievement and opportunity in the United States. For many generations, African Americans have lagged behind Whites in every available measure of cognitive ability and achievement (Loury, 1998). A difference in mean IQ between Blacks and Whites of about one standard deviation (15 points) has been amply documented (Jencks, 1972; Scarr & Weinberg, 1976). At the tails of distributions, moderate differences in means translate to gross differences in representation. When group means differ by 15 points, only 16% of the lower-scoring group exceeds the mean of the higher-scoring group (Gustafsson & Undheim, 1996). Although a gap of this magnitude is well established in Black-White comparisons, a similar lag can be found for Hispanic Americans (Rodriguez, 1992).

Differences in achievement across ethnic groups are not peculiar to the United States. Strikingly similar patterns of discrepant achievement among ethnic groups can be found in many other nations around the world. Japan is a good, although perhaps surprising, example. In Japan, the pariah-caste Barakumin have been subjected to prejudice for centuries, confined to ghettos, limited largely to butcher and tanner trades, and prohibited from marrying outside their group. They exhibit much lower academic achievement and career attainment than do mainstream Japanese and, notably, their mean IQ is about one standard deviation below that of the non-Baraku majority (De Vos & Wagatsuma, 1966). However, unlike Black and White Americans, there is no race difference between the Barakumin and the Japanese majority. To some observers, parallel gaps in achievement in Japan and the United States both reflect "early damage to self identity and self-respect vis-a-vis cultural expectations held toward the traditionally disparaged group" (De Vos & Wagatsuma, 1966, p. 262).

THEORIES OF INEQUALITY

The roots of racial inequality are complex, and several competing theories have been advanced to explain race differences in cognitive and social outcomes (Ogbu, 1978; Steele, 1999). One prominent theory, which was largely responsible for the social programs associated with the Great Society movement, is the doctrine of *cultural deprivation*. This is the idea that Black children are often poorly equipped

by their families with the cognitive skills and motivations necessary for success in mainstream society. A competing model, the *cultural conflict* theory, holds that Black children are not culturally deficient, but merely different, and are in fact prepared for life in a culture that differs from that of the dominant culture. According to this view, schools are often at fault for failing to capitalize on the cognitive strengths that Black children bring with them into the classroom. *Institutional inequality* theory holds that institutional structures established by the larger society preserve inequality. This theory places blame on the lower expectations held for black children, on inferior resources allocated for their education, and on policies that bar them from success-bound tracks.

By Ogbu's account, none of these explanations is quite right. Rather, racial inequality arises most fundamentally from the ascription of African Americans to caste status, in which *caste* refers to a socially reinforced system of stratification based on lower status ascribed at birth. If Ogbu is right, then African Americans have something in common with the Barakumin of Japan and the Harijan, or "untouchable," infracaste of India. By virtue of assignment to a caste, only certain social roles and attainments are permitted, and socialization experiences are geared to the prescribed possibilities. It is the caste status of African Americans, said Ogbu, that drives all social mechanisms that reinforce inequality. In mixed-race settings, the constant pressure to disprove cultural stereotypes can lead to "disidentification," or rejection of academic competition, which really amounts to a refusal to be complicit in a "game" in which African American students are not allowed to win (Steele, 1999).

Within the theoretical matrix sketched earlier, the position I have taken is closest to the cultural differences theory. Here, the concept of *aptitude* is relevant. Intelligence is a very general aptitude, but like all aptitudes it describes readiness to succeed within a context (Snow, 1996). When the context changes, different competencies become adaptive. The intelligence repertoire consists of a *limited* subset of capabilities that permit effectiveness, in which *effectiveness* will be defined somewhat differently across cultures and between individuals. The exact composition of the intelligence repertoire is acknowledged, therefore, to be sensitive to variations in the demands and affordances of cultures or subcultures, although many elements of the repertoire are likely to transcend cultures. The Black-White gap in IQ and achievement is partly an expression of differences in enculturation in the repertoire sampled by IQ tests. Yet, with respect to Ogbu's (1978) theory, the IQ gap should not be seen as simply reflecting cultural differences, but as traceable also to deeply entrenched prejudices and social structures that reinforce race-based inequality. This means that the educative experiences I refer to as the *cultivation of intelligence* cannot, in themselves, lift society from the quagmire of repression and social injustice that has been oozing for centuries. Any hopeful attempt to cure society of deep-rooted problems associated with race must face the complexity and moment of its underlying causes.

Nonetheless, to understand unequal opportunities and outcomes associated with race, one must take seriously differences between population groups in the acquired and culture-laced cognitive set that I identify as intelligence. The acquisition of that repertoire is estimated, albeit imperfectly, by IQ. This makes IQ truly important without being all-important. Some observers have suggested that differences in IQ test performance may reflect differing task motivation (Nisbett, 1995). However, the IQ gap is unlikely to be purely an artifact of differing motivation. Simply ascribing the gap to motivational differences is contradicted by the finding that the Black-White discrepancy on any cognitive test is a direct function of that test's *g* loading, an association that Jensen (1992a) referred to as the *Spearman hypothesis* (Spearman, 1927). However, as I argued in the previous chapter, saying that differences in IQ reflect real differences in the intelligence repertoire is *not* to say these differences are genetically prescribed.

The very idea that racial differences in IQ might be rooted in genetics is a source of unrelenting public interest, triggering vituperative outrage in some and quiet acceptance in others (Sowell, 1995). Scholars who study race and IQ have sometimes been accused of bigotry and even outright fraud (Wade, 1976).[1] Herrnstein and Murray, authors of the incendiary *Bell Curve*, may have been correct in claiming that although the topic of race differences in intelligence is taboo, people are privately fascinated by it. Murray even referred to writings on the subject as "social science pornography," a provocatively ambiguous comparison (DeParle, 1994, p. 50). In writing this book, I had no great desire to address the subject of race differences in IQ, and yet the social importance of the subject is too great to ignore. In the end, I found the message to be hopeful.

INDIRECT EVIDENCE

Is genetics responsible for race differences in IQ? The answer is unknown (Jensen, 1998). Genetic influences must be acknowledged as a *possibility*, but *only* a possibility, and one that does not have much evidence in its favor, let alone proof (Gustafsson & Undheim, 1996). In the last chapter, we saw that the practice of applying within-group heritability estimates to between-group data is mistaken (cf. Jensen, 1998). The point was made vividly in Lewontin's (1970) metaphor of seed corn. That model can be applied hypothetically to human beings. Imagine that in some dark future every human being has a clone who is relegated to low-caste status, subject to prejudice and squalid living conditions, restricted to menial labor, and provided with only poor-quality education. Social scientists then move in and discover that the IQ distributions of the two populations differ by one standard deviation in the expected direction. The social scientists also find that genetic factors explain a substantial fraction of the IQ variance in both privileged and subjugated populations, and in the combined population. Imagine that a heritability value for IQ is calculated at 0.5. It might then be tempting for social scientists to apply the 0.5 heritability value to explain IQ differences between the two groups. However, that would be a fallacy because the two populations, like the seed corn, would be genetically indistinguishable.

Of course, Black and White populations are *not* genetically indistinguishable. But genetic differences, per se, are not germane. The pertinent question—whose answer is unknown at this point—is whether Black and White populations differ in the frequencies of genes that are functionally instrumental to (not merely correlated with) cognitive performance. What is known is that there are large between-race differences in modal *experience*; or, returning to the seed corn metaphor, "Blacks and whites do not grow up, on average, in the same kind of pot" (Tavris, 1995, p. 63).

Race differences in modal experience begin before birth. For reasons that remain mysterious, infant mortality is about twice as common in African American than in White populations (Jensen, 1998). Low birthweight among urban African Americans has been found to be two to three times that of Whites and more affluent city dwellers (Rush, Stein, & Susser, 1980). As of 1994, incidence of low birthweight (<2,500 grams) among African American newborns (13.3%) was more than double that of White newborns (6.2%; U.S. Department of Commerce, 1997). Massive between-race differences in newborn health can be found historically. In a study of race and SES associations with pregnancy complications conducted in Baltimore hospitals in the 1950s, only 5% of high-SES mothers suffered pregnancy complications; this contrasted with 15% of low-SES White mothers, and 51% of non-White mothers (Pasamanick, Knobloch, & Lilienfeld, 1956). Perinatal complications have, in turn, been associated with much higher incidences of behavior problems, mental health disorders, learning impairments, and mental retardation (Joffe, 1982). Of course, many other experiential factors can be hypothesized to contribute to differences in Black-White IQ distributions. For example, the proposal that nutritional deficiencies contribute to Black-White IQ differences is, in Jensen's (1998, p. 508) words, a "promising hypothesis [that] . . . is well worth studying."

When there are systematic differences in environments, whether of differing soil types for corn or of differing experiential histories for people, heritability coefficients cannot be applied to explain between-group differences (Tavris, 1995). What is needed are data sources other than heritability coefficients, which are actually descriptive statistics that are sensitive to variation in experience and in gene frequencies. As data accumulate, the Black-White IQ gap seems more believably accounted for by differences in modal experience. Relevant here is the worldwide trend of rising IQs known as the *Flynn effect*, described earlier. These IQ shifts are too rapid to allow genetic explanations. The fact of rising IQ contributes viability to the idea that the Black-White IQ gap is environmental in origin (Flynn, 1998). After all, the magnitude of IQ gains is of the same order as the historical Black-White gap. To be specific, Black-White IQ differences have historically been calibrated at around 15 points, or one standard deviation, from

the 1930s to the 1980s. Yet, between 1930 and 1980, *both* curves shifted rightward about one standard deviation. In other words, the IQ distributions of 1980s Blacks is congruent with that of 1930s Whites; the identity of those two curves is separated only by time and attendant societal changes. By implication, a gap of 15 points "can easily result from environmental differences" (Neisser, 1998, p. 18).

DIRECT EVIDENCE

The Flynn effect supplies evidence that intergenerational differences in IQ on the order of one standard deviation, or greater, can be accounted for by nongenetic mechanisms. This constitutes *indirect* evidence that group differences in IQ of the same magnitude can also be explained by differences in typical experience. However, there is also *direct* evidence that Black-White IQ gap is environmental. Nisbett (1995, 1998; also Flynn, 1980) cited a set of studies that bear more directly on whether genes contribute to Black-White differences in average IQ.

The Minnesota Transracial Adoption Study

Of the research cited by Nisbett, only the Minnesota study on adoption provides any support for Herrnstein and Murray's claim that the Black-White IQ gap is genetic in origin. In this study, White ($n = 25$) and Black or mixed-race (Black-White) ($n = 130$) children were adopted into White families (Scarr & Weinberg, 1976, 1983). When the subjects were older adolescents (mean age of 18.5 years), the adopted White children had the highest IQs (mean IQ = 111.5), followed by mixed-race children (mean IQ = 109.0), and then children of two Black parents (mean IQ = 96.8). At first blush, it seems that this study supports the genetic doctrine. However, when the data are limited to Black children who were adopted before the age of 12 months, a different picture emerges. The average IQ of the Black early adoptees was 110, which was 20 points higher than the IQ of comparable children raised in the Black community, and 10 points higher than the population mean. For Black children placed before the age of 12 months, IQ correlations with adopted siblings were "embarrassingly similar" to those between natural siblings (Scarr & Weinberg, 1983, p. 264). It is true that the IQs of adopted Black children averaged 6 points below that of their White adoptive siblings, but this gap is small enough to be accounted for by differences in pre- and postnatal experiences prior to adoption. (IQ differences of 6 points or so are not unusual even among identical twins.) The same study showed that the IQs of adopted children were more strongly correlated with their biological mothers ($r = 0.34$) than with their adoptive mothers ($r = 0.21$), reinforcing the belief that genetic forces are not to be dismissed; but these correlations are both rather weak, accounting for, at most, 10% of the variance in IQ. More important, these correlations mask the *upward shift* in IQ enjoyed by the adopted children compared to their nonadopted peers. Again, we are confronted with the statistical independence of measures of association (i.e., correlations and heritability coefficients) and the actual levels of measured ability (i.e., IQ and mental age). Thus, quite in contrast to the inferences drawn by Herrnstein and Murray (1984) in *The Bell Curve*, the original investigators concluded that "genetic racial differences do *not* account for a major portion of the IQ performance differences between racial groups" (Scarr & Weinberg, 1983, p. 261, emphasis added).

Residential Schools

What about the other direct evidence cited by Nisbett? One study contrasted the cognitive ability of Black or mixed-race (West Indian) children with White (English) children in a residential preschool (Tizard, Cooperman, Joseph, & Tizard, 1972). Although the IQs of the parents were not known, the study had the advantage of controlling, roughly, for the quality of environmental enrichment experienced by children. Moreover, all children had been healthy, full-term babies, thus reducing the possible influence of large discrepancies in prenatal care. Children were tested between the ages of 2 and 5 years. Their measured IQs were approximately 103 for White residents and 108 for Black or mixed-race residents, a difference that Nisbett (1995, p. 38) provocatively called "compatible with the assumption of a slight genetic superiority for blacks." Of course, a single study might suggest an overturning of conventional thinking but cannot accomplish it; at least, however, the findings cast doubt on the doctrine of Black genetic inferiority.

Blood Group Studies

Two studies have capitalized on the fact that the African American population as a whole has a substantial degree of European ancestry (about 25%, on average), but which varies considerably between individuals (Jensen, 1998). According to Shockley's (1972) hypothesis, if Europeans are superior to Africans in IQ, then the IQs of African Americans ought to be a function of their degree of European-African admixture. In one test of this hypothesis, researchers estimated the association of European genotypes with various blood group genes, and then computed "odds coefficients" to rank-order Black subjects according to their probabilistic genetic similarities to African ancestors ("ancestral odds"), and to a local Caucasian reference group ("sample odds"; Scarr, Pakstis, Katz, & Barker, 1977). None of the correlations between the two indexes and five measures of cognitive ability differed significantly from zero. Correlations between the first principal component of cognitive measures, estimating g, and "White blood-genes" were -.03 for ancestral odds and -.05 for sample odds. Both values were trivial and statistically insignificant.

In a similar study, 16 blood group genes were ordered according to their representations in Black and White populations (Loehlin, Vandenberg, & Osborne,

1973). The blood group gene that most differentiated between the two populations was labeled Fy^a, and was present in 80% of Whites and 22% of Blacks. The rank-order correlation between the ordered list of genotypes (which indexed the "Europeanness" of blood type) and the associated IQ of Black adolescent subjects was -.38, with higher IQ values associated with *non-European* genotypes. Although this correlation was not statistically significant, perhaps owing to the small sample size (n = 42), the direction of the association is provocative, to say the least. In fact, the blood group gene Fy^a, which was most characteristic of the White subjects, was *negatively* correlated with IQ in both White subjects (r = -.21) and Black subjects (r = -.35), although again these correlations were not statistically significant. In another sample studied by the same investigators, the correlation between Black subjects' IQ and "White blood-genes" was a trivial +.01 (again statistically insignificant). Point-biserial correlations between individual blood genes and IQ were also trivial, ranging from +.03 to -.09 in the White sample.

Blood group studies have been criticized for their lack of power to detect gene-IQ associations. One weakness of the methodology is that the independent assortment of genes across generations is certain to dissociate blood genes from those that are hypothetically associated with cognitive ability. Given Jensen's (1998) claim that European genes were introduced primarily during the period of American slavery, the fact of many subsequent generations has made the independent segregation of gene alleles a serious problem. One exception cited by Jensen is the blood gene Fy, which (as noted previously) most discriminates between Black and White populations but has not been shown to correlate with IQ. For now, Shockley's (1972) hypothesis that the degree of racial admixture can predict g has found zero support, but whether the blood group studies had the statistical power to test the hypothesis adequately is not clear.

Gifted Black Children

Another, older study followed a logic similar to that of the blood group studies—namely, that the degree of Black-White admixture ought to predict cognitive ability if the genetic hypothesis of race differences is correct. Investigators examined two groups of high-IQ children in suburban Chicago, one with IQs of 125 and above (labeled "superior"), and the other with IQs of 140 and above (labeled "gifted"; Witty & Jenkins, 1934, 1936). The idea was that if race differences in IQ were genetically based, a high degree of Caucasian ancestry should be more typical of high-IQ Black children than of the Black population generally. Parents of participating children were asked to identify their child's racial mixture, in sixteenths, and on the basis of these self-reports the children were classified into one of four groups based on degree of European background. Witty and Jenkins found that children in both high-IQ groups were slightly *less* likely to have substantial European ancestry than the U.S. Black population as a whole (distributional differences were not statistically significant, however). In both high-IQ groups, the highest scores were obtained by students with *no* reported Caucasian ancestry. In summarizing these findings, the investigators placed their study in the context of similar research, which on the whole showed that "superior intelligence test ability is *not* exhibited by those Negroes having the largest amount of white ancestry" (Witty & Jenkins, 1936, p. 187, emphasis in original).

Mixed-Race Children

A fascinating study by Eyferth (1961) focused on the offspring of American fathers (Black and White GIs) and German mothers conceived during the Allied occupation of Germany following World War II (Eyferth, 1961).[2] Eyferth matched triads of two "Black" (i.e., mixed-race) children and one White child (Ns = 181 Black and 83 White) for age, gender, number of siblings, school experience, locale of residence, and the socioeconomic background of the custodial parents (natural mothers or foster parents). Flynn (1980) scrupulously evaluated Eyferth's data for the possibility that African American troops were either unrepresentative of the U.S. Black population, or that sexual contact between GIs and German women was uneven across military ranks (and therefore possibly IQ). Flynn concluded, however, that neither factor undermined Eyferth's data: African American soldiers in the occupation forces were representative of the U.S. Black population within about 3 IQ points,[3] and American-German sexual liaisons were not only common but as characteristic of high-ranking officers as of privates. Eyferth's major finding was that there was essentially no difference in IQ between the offspring of Black GIs (mean IQ = 96.5) and White GIs (mean IQ = 97.2). The conclusion drawn by Flynn (1980, p. 95), and shared by Eyferth (1961), was that "whatever IQ gap existed between black and white fathers was absent in the offspring and was therefore environmental."

A final study cited by Nisbett (1995) focused on the mixed-raced children of one White parent and one Black parent (Willerman, Naylor, & Myrianthopoulos, 1974). The question was whether there was any relationship between the parents' gender/race configuration and their child's IQ. In other words, if a child has one Black parent and one White parent and the goal is to predict cognitive outcomes, does it matter which parent is Black and which is White? Participating Black and White mothers were similar on pertinent background variables, including SES and income, and their children were similar on perinatal variables, such as gestation length and birthweight. However, the investigators found that the children of White mothers (and Black fathers) had nearly a 10-point IQ advantage over the children of Black mothers (and White fathers). When the data were adjusted for small group differences in maternal education, the IQ gap reduced to about 7 points. Most of that gap was accounted for by the depressed IQ scores of male children of Black mothers. Because participating children were genetically comparable in terms of race (half Black/half White), and because mothers have tended to be

"the primary agent of socialization in the early years," the most straightforward interpretation of the 7- to 10-point IQ difference is that it arose from different socialization experiences (Willerman et al., 1974, p. 84). Although the content of differential experience was not investigated, genetic explanations for the gap appear to be implausible.

As Nisbett (1995) recognized, none of the studies cited is beyond critique. One design weakness involves the possibility of parents' self-selection in the case of mixed-race offspring—Black parents might have higher IQs or White parents lower IQs than in the general population. Nisbett (1995) countered, however, that the magnitude of the demonstrated effects would require a degree of self-selection that is "implausibly great" (p. 41). Also, because similar conclusions were reached in studies conducted in different circumstances, times, and locales, the artifact-of-selection argument is weakened. And, despite design weaknesses of the studies cited by Nisbett, they are arguably more representative of the research literature than is the "highly selective" subset cited by Herrnstein and Murray, that ostensibly supports (but in fact does not) a hereditarian position (Nisbett, 1995, p. 42). A more thorough examination of the research literature leads to a rather different conclusion. Nisbett (1995) summarized: "So what do we have? There are a total of seven studies providing direct evidence on the question of a genetic basis for the B/W IQ gap. Six of them are consistent with a zero genetic contribution to the gap (or with very slight African superiority) based just on the raw IQ numbers" (p. 41).

Others concur. On reviewing the literature on Black-White differences in measured intelligence, Brody (1992, p. 309) concluded that "there is no convincing direct or indirect evidence in favor of a genetic hypothesis of racial differences in IQ." Even Herrnstein and Murray equivocated. Although they maintained that it is "highly likely" that genetics contributes to race differences in IQ, they refused to say just how much (Herrnstein & Murray, 1994, p. 311). Kaus (1995, p. 134) retorted: "In other words, the genetic contribution could be 50 percent, it could be 1 percent, or .001 percent for all they know. Or (though it is not 'likely') it could be zero." Indeed, after decades of research on the question of race and IQ, the hypothesis of *zero* genetic contribution to race differences remains both plausible and defensible.

THE GAP CLOSES

The hopeful news is that the race-defined gap associated with IQ and academic achievement is shrinking (Herrnstein & Murray, 1994; Neisser, 1998; Nisbett, 1995; Sternberg, 1996b). A shrinking cognitive gap has theoretical importance but also, possibly, profound social consequences. This is because, more than ever, social opportunity is mediated by cognitive ability, and (as we will see) this is true both within and across racial-ethnic groupings.

The once intractable Black-White IQ gap of one standard deviation (15 points) is starting to close. In 1991, Vincent used data from norming studies of major IQ tests to show that Black-White IQ discrepancies have shrunk in the post-Civil Rights era. The key year is 1980. Studies conducted after 1980 show a Black-White difference of 7 to 12 IQ points among children. When SES is controlled, these differences are even smaller, 1 to 9 IQ points. Humphreys (1988) obtained similar data supporting a somewhat more moderate gap shrinkage. The closing IQ gap is exemplified in Raven's Standard Progressive Matrices, which before 1980 registered a Black-White difference of 16 points among adults, but after 1980 a gap of only 7 points, or about one half standard deviation, among 12-year-old children. What is causing these IQ shifts? No one knows for sure, but a likely candidate is the complex of societal transformations spurred by policy, legal, and judicial decisions launched in the Civil Rights era, which resulted in a more open society. Vincent's (1991, p. 269) interpretation of these changes was that "Black/White IQ differences are in a very real sense a barometer of educational and economic opportunity," and that "the quarter-century push toward equal opportunity in the United States is finally beginning to show results."

Black-White differences in academic achievement have also shrunk (Hunt, 1995). Grissmer and colleagues documented a rapid rise in academic achievement between 1970 and 1990, during which the verbal and mathematics ability of Black students increased in the range of 0.4 to 0.8 standard deviations (Grissmer, Williamson, Kirby, & Berends, 1998). This jump in achievement among millions of children is "rare and perhaps unprecedented" (p. 252). Between 1971 and 1996, the Black-White gap in reading ability shrank by almost one half (from 1.25 to 0.69 standard deviations), and the Black-White gap in mathematics achievement closed by about a third (from 1.33 to 0.89 standard deviations; Jencks & Phillips, 1998a, 1988c). A narrowing of the Black-White achievement gap can be found in nearly every subject and every grade assessed in the National Assessment of Educational Progress (NAEP) since its founding in the late 1960s. The escalating trend lines for reading and mathematics achievement among black students is illustrated in Fig. 7.1.

Trend data on IQ and academic achievement tell the same story. The cognitive gap separating the means of Black and White students is shrinking approximately 2.5 IQ points per decade, stabilizing at about 10 points in 1990. The gap may have continued to shrink in the 1990s: More recent data indicated a Black-White IQ gap of between seven and ten points (Nisbett, 1995). As suggested graphically in Fig. 7.1, the narrowing of the gap is explained not by falling White scores, but instead by rising Black scores, a pattern that Herrnstein and Murray (1994, p. 291) called "an encouraging picture." Although the pace of the gap shrinkage may have slowed in the past few years, the convergence of IQ and achievement curves makes two points quite forcefully: Cognitive ability, as estimated by IQ and manifest in achievement, is not an unalterable fixture; and it is neither nonsensical nor contrary to data to think that the Black-White IQ gap can close completely (Jencks & Phillips, 1998c).

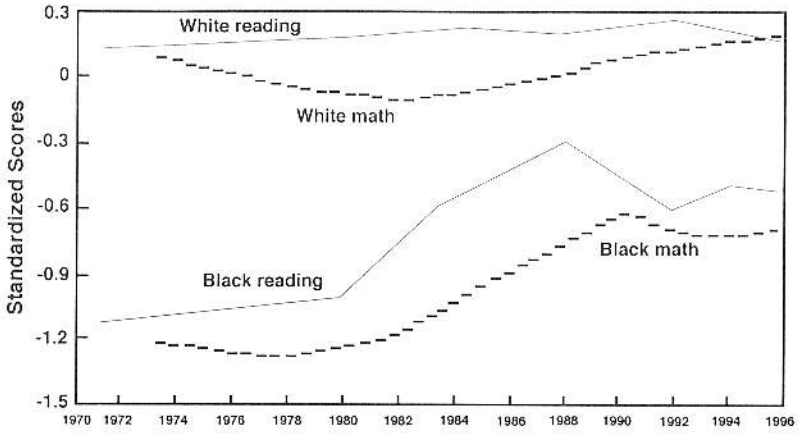


FIG. 7.1. U.S. Reading and mathematics scores for Black and White 17-year-olds. Tests score means for all years are presented in a common metric based on a 1996 mean of zero and a 1996 standard deviation of one. From "The Black-White Test Score Gap: An Introduction," by C. Jencks and M. Phillips, in *The Black-White Test Score Gap* (p. 4), by C. Jencks and M. Phillips (Eds.), 1998, Washington, DC: The Brookings Institution Press. Data Source: National Assessment of Educational Progress. Copyright 1998 by the Brookings Institution. Reprinted with permission.

Vincent (1991) suggested that the closing of the cognitive gap is a reflection of more equitable educational and economic opportunity. Grissmer et al. (1998) tested this idea analytically by modeling the relationships between family and demographic characteristics and student achievement for the U.S. school population as a whole. In doing so, they used the nationally representative data sets of the National Longitudinal Survey of Youth (NLSY) and the National Education Longitudinal Survey (NELS). They found that the most powerful predictor of reading and mathematics achievement was parents' education, which had an independent effect of about 0.5 standard deviations when other variables were controlled. This effect was much larger than that of the next most important predictor, family income, which had an independent effect of between 0.1 and 0.2 standard deviations. Once these predictive equations were generated, the investigators plugged in values for the changing demographic characteristics of minority families between 1970 and 1990. They then compared the predicted gains in academic achievement to the actual gains reported by the National Assessment of Educational Progress (NAEP). The equations worked fairly well for the White students, but they dramatically *under*predicted achievement gains for Black students and, to a lesser degree, Hispanic students, accounting for only about one third of the achievement gains.

The underprediction of achievement gains implies that changes in family characteristics alone cannot account for the rise in mathematics and reading scores among Black students. The investigators found, in fact, that regional differences in score gains coincided with changes in public policy and law that impacted regions differently, such as school desegregation in the South (Grissmer et al., 1998). None of this reduces the importance of family-demographic characteristics: The data clearly show that changes in parents' education, family size, and family income have had a positive effect on the academic success of the subsequent generation of Black and Hispanic children. To be specific, between the mid-1970s and 1990, Black families became smaller and parents attained higher education levels. The cognitive gains associated with these changes were offset somewhat by births to younger and single mothers, which had small but detectable negative effects on children's achievement. For Hispanic families, increases in parental education were smaller, as were reductions in family size. In the Hispanic population, these changes and associated academic outcomes were probably complicated by the arrival of immigrants during this period (Grissmer et al. 1998).

Grissmer et al. (1998) portrayed the last few decades of the 20th century as "a major 'experiment' " in American social and educational policy, an experiment marked by intense investment in disadvantaged children and families. This investment has resulted in rising incomes and improvements to education, health care, nutrition, and housing (p. 254). Public spending on programs devoted to children more than doubled (in constant dollars) from 1960 to 1988, and these funds were spent disproportionally to the benefit of low-income and minority children. During the past 4 decades, Black families have made large socioeconomic gains. From 1959 to 1995, the percentage of Black workers who held low-skilled jobs dropped steeply, whereas the percentage of those holding "good" and "elite" jobs grew (Carnevale & Rose, 1998). The facts of rising representation of African Americans among the middle class and the affluent, and of concomitant reductions in the cognitive gap, argue that the sustained public commitment to creating a more equitable society (with peaks and valleys duly acknowledged) has not been in vain.

Interestingly, the social changes concomitant with the rise in minority test scores, especially those of Black students, are not unlike those transformations that accompany more gradual cognitive gains in Western countries. The parallels suggest that there may be a larger pattern of causal forces underlying both the closing of the Black-White gap in the United States and the global Flynn effect. In fact, the rapid rise in the cognitive proficiencies among American Black students might be viewed as "mini" Flynn effect—smaller in scope, but more vigorous in execution (Grissmer et al., 1998). Neither is connected with genetic factors; both are fundamentally environmental in origin. The argument that environmental factors are responsible for the upward burst in cognitive outcomes among minority youth is so compelling that the hereditarians Herrnstein and Murray (1994) conceded: "In a period as short as twenty years, environmental changes are likely to provide the main reason for the narrowing racial gap in scores" (p. 292). In response, Kaus (1995) chided the authors: "Sounds like the environment may ultimately explain everything!" (p. 133).

SOCIAL PROSPECTS

The one-two punch of rising IQs and closing IQ gaps has radically reshaped the terms of discussion about race, intelligence, the environment, and social evolution. The new data hint at possibilities that were formerly (at least for many) unthinkable. If these trends continue, a narrowing cognitive gap could go a long way toward reaching, at last, the agonizingly elusive dream of racial equality, and fulfilling American precepts that have cruelly tantalized generation after generation. Some observers go so far as to say that the way to reach social equity is through cognitive equity—that cognitive gains and social gains are yoked and move in tandem (Kornhaber, 1998). There is no reason why the process now set in motion shouldn't continue. However, let us be as clear as we can about our goals and the means to achieve them. The explicit adoption of a new driving goal of education—the enhancement of intelligence for all—might foster those powerful cognitive abilities that enable more learners to pursue high academic and career attainment, and higher earnings. What makes this possible is that the cognitive ability/earnings linkage is now (although not formerly) an equitable one, marked by near-parity of earnings by Black and White workers of the same cognitive ability, especially in the high-IQ band (Jencks, 1972; Jencks and Phillips, 1998c). Furthermore, when Black and White 12th-grade students have the same cognitive test scores, it is *Black* students who are more likely to complete college. Greater educational attainment, in turn, is likely to improve employability, earnings, and quality of life. Jencks and Phillips (1998c) made the bold assertion that eliminating the cognitive gap is "probably both necessary and sufficient for substantially reducing racial inequality in educational attainment and earnings" (p. 4).

Obstacles remain. Differences in cognitive ability and achievements derive from several knotty sources, including patterns of parent-child interaction, teacher expectations, and lingering oppression. Black and White children still differ profoundly in modal experience. These include differences in the typical quality of schooling, an inequity that has particularly dire implications for the gifted Black child (Witty & Jenkins, 1934). There is some direct evidence, elaborated in the next chapter, that poor quality of schooling can actually lead to an IQ decline over time, and that differences in quality of schooling might partially account for Black-White differences in IQ (Jensen, 1977). Bigotry and discrimination are still snares. Stereotypes are especially insidious when they are consistent with statistical means—and it may be that "eliminating such stereotypes depends on changing the facts" of differing cognitive ability distributions (Jencks & Phillips, 1998b, p. 71). A renewed optimism, based on data, is building around the idea that cognitive parity is achievable. Ability curves are shifting rightward; eventually, they may coalesce.

CONCLUSION

For many decades, the typical response to evidence or claims of group differences in IQ has been outrage or quiet acceptance. Neither reaction is helpful to scientific or social progress. Group differences can be faced honestly without taking them as destiny. Instead, they are descriptions, report cards on what society has produced. Decades of research support the claim that the Black-White difference in mean IQ is a quantifiable manifestation of deep social inequities, not a Galtonian cause.

More than 50 years ago, Lorge discerned a three-way linkage among intelligence, education, and equity. He wrote, "Society must recognize that the restriction of educational opportunities because of race, color, and economic circumstances may mean the attenuation of its chief human resource—the functioning intelligence of its citizenry" (Lorge, 1945, p. 492). Logically, it follows that greater educational opportunity will result in greater intelligence for all segments of society. However, the relationship is reciprocal: Greater intelligence can also *create* greater opportunity as intellectual and life options expand. This reciprocity is nicely captured in Snow's (1982a) dictum that intelligence is "education's most important product, as well as its most important raw material" (p. 496). Intelligence and education are transactional and mutually reinforcing. Their alignment could lead to a freer and more prosperous world, and to one that conforms more nearly to the ideals of equality, democracy, and opportunity.

NOTES

1. The most infamous example involves data (supporting a high heritability for IQ) reported by Sir Cyril Burt, which at minimum were carelessly handled and, at worst, fabricated (Kamin, 1974; Wade, 1976). In another example, Gould (1981, pp. 160, 168, 172) discovered evidence that the "unsubtle hereditarian," H. H. Goddard, altered photographs of the Kallikak clan (illegitimate descendants of a "feeble-minded tavern wench") to create "an appearance of evil or stupidity."

2. Eyferth's (1961) study also involved "occupation children" of French troops, both White and Black, but Flynn (1980) demonstrated that data from these children do not affect the overall conclusions drawn by both Eyferth and Flynn.

3. Jensen (1998) noted that among prospective Army recruits, 30 percent of Blacks failed the preinduction mental test compared to 3 percent of Whites, raising questions about the representativeness of black soldiers to the Black male population of the U.S. as a whole.

8

Intelligence and Experience

"IQ, *g*, and school achievement are all massively affected by environmental factors"—so concluded Ulric Neisser (1998, p. 21) after summarizing a bounty of recent data bearing on the topic. The data show that preconceptions about the fixedness of intelligence are unwarranted; rather, intelligence is plastic. It can shift in form and degree both within persons and across generations. This chapter explores the plasticity of intelligence by considering what *kinds* of experience are known to stimulate or stunt its development.

For convenience, experiences that bear on intelligence development are divided into seven categories: prenatal experience, family experience, school experience, university experience, job experience, experience in old age, and a seventh category, nutrients and toxins, which spans the life stages. Experiences at each stage are not independent, but instead function as contingent sieves that limit or expand readiness to profit from experience at subsequent stages. Operative all along the developmental continuum is a law of cumulative advantage in which the cognitively rich become richer still. Aptitudes, including intelligence, always represent both finished work and foundation, product and raw material, an achieved "quality or power that makes possible the development . . . of some further quality or power" (Snow, 1991, p. 250).

Because the educative quality of experience is cumulative and contingent, education itself can be redefined to consist of all those varied experiences that enrich a person's ability to benefit from future experience. Dewey (1938) defined educative experience as having a certain quality that he called *continuity*. By this, he meant the ability of an experience to live on fruitfully in the future, and insisted that all experiences worthy of the term *education* must satisfy this criterion. Quality of experience is everything, and experiences all along the life sequence can vary in educative quality. If intelligence is defined to consist of those functions that permit future effectiveness, then an alignment obtains between the intelligence repertoire and Dewey's criterion of continuity. The cultivation of intelligence then becomes possible only through those experiences that are most justifiably called *education*.

PRENATAL EXPERIENCE

At the conclusion of a 40-week pregnancy, newborns differ in the degree to which they have experienced nutritive environments and been spared exposure to toxic

ones. These experiential differences have long-term consequences for development, including cognitive development. Thus, experience can be educative or noneducative, even from the moment of conception.[1] In behavior genetics research, prenatal effects are often assumed to be negligible (Devlin, Daniels, & Roeder, 1997). However, the contribution of prenatal experience to IQ can be estimated in behavior-genetic models by introducing a term for maternal effects, including the environment in utero. The magnitude of these effects has been estimated at $h^2 = 0.2$ for twins, or about 40% of all nongenetic effects on IQ (Devlin et al., 1997). This estimate underscores the tremendous importance of the prenatal environment for optimizing the cognitive development of children, and has direct implications for how intelligence might be enhanced on a large scale (Devlin et al., 1997).

Toxins and Trauma

Prenatal exposure to neurotoxins, teratogens, and mechanical injury can find later expression in the health and functioning of the child. Known deleterious agents include alcohol, cigarette smoke, pesticides, radiation, and drugs (including obstetric medications). Maternal exposure to the sedative phenobarbital, for example, has been linked to depressed IQ scores in adults. After controlling for background variables, exposure to phenobarbital during pregnancy can produce a negative effect of at least 0.5 SD, or 7 IQ points (Reinisch, Sanders, Mortensen, & Rubin, 1995). Environmental contaminants also have documented negative effects. Through biomagnification at higher levels in the food chain, the environmental toxins methylmercury and polychlorinated biphenyls (PCBs) are found in high concentrations in the fatty tissues of contaminated fish. If large amounts of contaminated fish are consumed during pregnancy, these toxins can disrupt prenatal neural development and, in the case of PCBs, may result in depressed IQ scores when children reach school age (Jacobson & Jacobson, 1996; Joffe, 1982; Marsh et al., 1995). Even maternal stress can threaten neurological development. In rhesus monkeys, pregnant females exposed to chronic stress have offspring that suffer permanent neurological impairment (Nelson, 1999). In humans, moderate-to-severe maternal stress (presumably mediated by stress hormones, e.g., glucocorticoids) has been linked to neurological "nonoptimality" and smaller head circumference—a coarse measure of brain size—in newborns (Lou et al., 1994). Birth trauma, including anoxia, can also have harmful effects on the CNS, perhaps contributing to learning disabilities or cerebral palsy.

Prenatal exposure to alcohol is notorious for its vitiating effects on cognitive and physical development. Fetal alcohol syndrome is identified with facial abnormalities, growth deficiency, and dysfunction of the central nervous system. Mean IQs for children with fetal alcohol syndrome are typically in the range of 65 to 75, and as much 35 points below the mean IQ of matched controls (Mattson, Riley, Gramling, Delis, & Jones, 1997). Fetal alcohol syndrome is widespread, affecting more than 8,000 newborns every year. However, the number of children

chronically exposed to alcohol in utero is much higher, roughly 12 times that number, or about 100,000 births each year. Most alcohol-exposed children display none of the physical characteristics associated with fetal alcohol syndrome, and yet they too have significantly depressed IQ scores. In one study, alcohol-exposed but structurally normal children had a mean IQ of 84, which was 25 points below that of matched control children (Mattson et al., 1997).

Adverse environmental effects are not limited to maternal exposure (Joffe, 1982). In animal studies, male exposure to lead, morphine, methadone, alcohol, and other agents has been linked to deleterious effects on progeny, including low birthweight, increased mortality, and decreased learning ability. In men, exposure to lead, anesthetic gases, cigarettes, and caffeine have all been associated with negative effects on offspring, including a higher incidence of low birthweight and spontaneous abortions. Smoking, for example, has been associated with depressed maternal weight gain during pregnancy and with low birthweight (Rush, Stein, & Susser, 1980). In turn, small-for-date newborns (i.e., those whose birthweights are lower than expected, given the gestational age) are at greater risk for impaired development (Joffe, 1982).

Infection

Prenatal exposure to infectious agents also contributes to the risk of impaired cognitive development. For example, infection by the cytomegalovirus (CMV), which is found in about 1% of all live births, has been linked to IQ decrements and other impairments (Scheiner, Hanshaw, Simeonsson, & Scheiner, 1977). Most infants with congenital CMV infections are born to young, disadvantaged mothers, who are least likely to provide the rich home environments that could compensate for their child's compromised health status. CMV and other intrauterine infections "may contribute significantly to the incidence of developmental retardation" among the poor and, by implication, to cognitive differences among racial/ethnic groups statistically associated with poverty (Breitmayer & Ramey, 1986, p. 1152).

Placental Blood Supply

Evidence that in utero experience can have significant consequences for cognitive development has been found in studies of identical twins. There is a mild IQ disadvantage associated with twins generally, an effect linked to higher incidences of prematurity and low birthweight, and to the necessity of sharing intra-uterine resources. Differences in midpoint birthweights between pairs of twins can account for between-pair IQ differences as large as one standard deviation. In Storfer's (1990) analysis, twins that were relatively heavy at birth had IQs in the range of 105 (for weights > 6 pounds) to 113.1 (for weights > 7 pounds), whereas lighter twins (weights < 4 pounds) had an average IQ of 96.2.

Monozygotic (MZ) twins, although genetically identical, can also differ phenotypically, even at birth. For example, they often exhibit substantial *within-pair* differences in birthweight (averaging about 300 grams, or 10% of birthweight) and IQ (averaging 6 points; Storfer, 1990). The heavier twin typically enjoys an IQ advantage, and that advantage becomes larger as within-pair weight discrepancies increase and as birthweights decrease. When one or both twins weighs less than 6.5 pounds, the cognitive advantage associated with the heavier twin is about 9 IQ points, suggesting that IQ effects appear below some prenatal nutritional threshold. Storfer found effects on the order of 6 IQ points for low-birthweight twins, excluding from his analysis data on seven pairs of Black twins because their birthweights were "extremely low and their IQ scores averaged only 72" (1990, p. 13).

Other investigators have found that whether monozygotic (MZ) fetuses share a chorion (outermost) sac, or each has a separate chorion, also has an effect on IQ variation during childhood (Rose, Harris, Christian, & Nance, 1979). When monozygotic twins share a chorion, they also share a placenta and have a common blood supply. In dichorionic MZ twins, each has a separate chorion and (at least initially) an independent placenta and blood supply (placentas merge in 40% of cases). Differences in the quality and efficiency of placentas may contribute to within-pair IQ variation. IQ variation is greater in dichorionic twins than in monochorionic twins, a finding that reinforces the "rather considerable influence of the prenatal environment on . . . intelligence" (Melnick, Myrianthopoulos, & Christian, 1978, p. 428).

Vitamin and Protein Supplementation

The ingestion by women of vitamin supplements during pregnancy can have a positive effect on their children's IQ scores. In Harrell's classic study conducted in Norfolk, Virginia, poor pregnant women, 80% of whom were Black, were given daily vitamin/mineral supplements (Harrell, Woodyard, & Gates, 1955). The Stanford-Binet Form M was administered to their children at the ages of 3 and 4 years. Children whose mothers had received supplementation during pregnancy had an IQ advantage on the order of 4 to 8 points over children whose mothers had received a placebo.

A similar study carried out by Rush and colleagues involved protein and vitamin/mineral supplementation in the diets of expectant Black women (Rush et al., 1980). The effects of protein supplementation were not entirely as predicted or hoped: There was, unfortunately, a higher incidence of fetal demise in the experimental group—with no ready explanation. At 1 year of age, however, children in the experimental group displayed faster stimulus habituation and had longer play episodes (but not higher IQ scores), outcomes that are regarded as signs of cognitive development. The investigators concluded that nutrient supplementation during pregnancy probably exerts cognitive effects, but only in cases where prenatal malnutrition is likely to be severe.

Breastfeeding and DHA

Both the practice and duration of breastfeeding have been statistically associated with cognitive development. In a longitudinal study conducted in New Zealand, Horwood and Fergusson (1998) found that the duration of voluntary breastfeeding was mildly but positively predictive of WISC IQ (at ages 8 and 9), reading and mathematics achievement (at ages 10 and 12), and high school examination scores (at age 18). When the effects of confounding influences (e.g., SES and smoking) were removed through regression analysis, a "small but detectable" effect remained for breastfeeding (Horwood & Fergusson, 1998, p. 6). Children who had been breastfed for at least 8 months had an IQ advantage of about 4 points over those who had not been breastfed at all. Although this result is consistent with other research findings, a causal link between breastfeeding and higher IQ cannot be established with certainty because the correlation may ultimately be explained by other, as-yet unidentified confounding factors (Krugman & Law, 1999).

Some investigators, including Horwood and Fergusson (1998), suspect that any cognitive advantage conferred by breastfeeding might be traced to the presence in breast milk of the long-chain fatty acid known as *docosahexaenoic acid* (DHA). DHA is a structural component of neural tissue, including brain tissue, but it cannot be synthesized by the human body and thus must be obtained in the diet. At the time of writing, DHA is not an ingredient in infant formula produced in the United States, although it is used in Europe and Asia. The question of whether DHA ought to be added to infant formula is a contentious issue on both scientific and political grounds (bottle feeding is much more common among poor mothers; Kaufman, 1999). DHA supplementation has been associated with superior visual acuity in infants, and there is some evidence for its ability to enhance infants' performance on problem-solving tasks (Birch, Hoffman, Uauy, Birch, & Prestidge, 1998; Willatts, Forsyth, DiModugno, Varma, & Colvin, 1998).

As the launching point for all further human development, prenatal experience matters. The relevance of prenatal experience to all subsequent experience is a point that is sometimes missed or ignored when behavior geneticists parcel effects into genetic and socialization causes. For example, when adopted children resemble their biological parents, some of that covariation may be related to differences in prenatal experience. Typically, that variance is neatly co-opted into the genetics bucket (Scarr, 1997), even though for the fetus it is experiential (genetic factors may also be involved, of course). Pertinent, here, are the well-known modal differences in health status between Black and White newborns. Variation in prenatal experience may help explain group IQ differences. If so, redressing group differences in prenatal experience could contribute to greater equity of cognitive experience and, therefore, cognitive outcomes. Jensen (1998) acknowledged, for example, that Black-White IQ differences might be partly "attributable to the combined effects of LBW [low birthweight] and a low frequency of breastfeeding" (p. 507). Other investigators have suggested that "interventions aimed at improving the prenatal environment could lead to a significant increase in the population's IQ" (Devlin et al., 1997, p. 470).

FAMILY EXPERIENCE

By any criterion, the family is a potent medium for cognitive growth. For better or worse, parents are their children's educators and the home is a "classroom" that can impede or advance the development of each child (Sigel, Stinson, & Kim, 1993). Discerning the interactions between school and family effects on learning, Heyns (1978) concluded that "the role of families in the achievement process is ubiquitous; few educational outcomes can be unequivocally dissociated from parental influences" (p. 185). However, does family experience influence the development of intelligence as such? Several streams of evidence, including behavioral genetics, now answer this question in the affirmative (Thomson & Plomin, 1993). Such data highlight vast differences in the home experiences of children, differences that are related to socioeconomic class and that are manifest in the linguistic, literary, emotional, and sensory qualities of daily life.

Home Environment

Independent of SES, the quality of the home environment impacts children's cognitive development. In a multisite study, a consortium of researchers used the Home Observation for Measurement of the Environment—the HOME inventory—to identify which features of the home environment are most strongly associated with cognitive growth (Bradley et al., 1989). Table 8.1 displays some of the correlations found among the cognitive and emotional richness of the home (as measured by the HOME inventory), maternal education, children's cognitive development (MDI—Mental Development Index) at 24 months, and IQ at 36 months. MDI and IQ scores correlated approximately 0.50 with measures of cognitive simulation, especially the availability of play materials, the interaction of the primary caregiver with the child, and the variety of experiences presented to the developing child. Correlations of about 0.50 were also found between maternal education and aspects of the home environment related to cognitive stimulation; somewhat lower correlations were found between maternal education and emotional support.

Although SES was moderately correlated with HOME scores (again, approximately 0.50), the quality of parental care varied considerably *within* socioeconomic groups. Regression analysis supported the assertion that the home environment is more potent than SES in shaping a child's cognitive development. When two variable sets—SES and HOME—were entered into regression equations in alternate orders, HOME scores accounted for much more residual variance in

TABLE 8.1
Qualities of Home Environment and Children's Cognitive Development

Age/HOME Subscales	*Maternal Education*	*MDI (24 months)*	*IQ (36 months)*
24 months			
Responsivity	.28	.40	.47
Acceptance	.25	.33	.39
Organization	.20	.22	.31
Play materials	.50	.53	.52
Involvement	.49	.55	.54
Variety	.34	.42	.45
Total	.50	.58	.62
36 months			
Learning stimulation	.40	.47	.49
Pride and affection	.09	.28	.34
Total	.38	.50	.54

Note. HOME = Home Observation for Measurement of the Environment; MDI = Mental Development Index. From "Home Environment and Cognitive Development in the First 3 Years of Life: A Collaborative Study Involving Six Sites and Three Ethnic Groups in North America," by R. H. Bradley et al., 1989, *Developmental Psychology, 25*, p. 222. Copyright © 1989 by the American Psychological Association. Adapted with permission.

cognitive outcomes than did SES. Stronger relations between HOME variables and cognitive scores were found for middle-class families than for either lower-middle-class or lower-class families.

Because the data reported in this study are correlational, it is possible that the cognitive richness of the home does not produce differences in cognitive development, but instead reflects them. One could imagine, for example, that some parents will actively seek ways to stimulate a child who shows above-average cognitive ability early in life. There is actually some evidence for this effect: Positive (but low) lag correlations were found between MDI scores and HOME scores obtained 1 year later. However, lag correlations were much more robust in the other direction: HOME scores more strongly predicted MDI scores a year later. On the basis of this difference, Bradley et al. (1989) concluded that "the primary direction of effect was from environment to development" (p. 231). It is also possible that qualities of the home environment are confounded with genetics—that is, some parents might be more inclined than others, genetically, to provide home environments that are cognitively rich. However, even if this were true, it is unlikely that experientially proximal variables, such as the quality of parent-child interactions, are epiphenomenal. Moreover, there is no obvious reason why intelligence-promoting parenting strategies cannot be taught and learned, a fact that has been recognized in many intervention projects.

Among Black families, correlations between home environment variables and cognitive development were rather weak, and even smaller correlations were found among Mexican American families. Bradley et al. (1989) acknowledged that the weak correlations might be artifacts of the research design. Alternatively, the weak correlations might be related to the confounding of race/ethnicity with SES, and to the consequent restriction of range on the HOME inventory for these subsamples. Within these groups, however, the availability of stimulating play materials was moderately related to cognitive development. Also, among Black children, "pride and affection" were moderately correlated ($r = 0.53$) with IQ at 36 months.

Other studies have also demonstrated positive relationships between the quality of the home environment and early cognitive development (e.g., Brooks-Gunn, Klebanov, Liaw, & Spiker, 1993). Ho (1987) found that the relationship between a mother's interaction with her child and the child's cognitive development is not adequately described by main effects. Maternal responsivity at age 12 months interacted with children's cognitive status, and did so in an interesting way. At 24 months, the slope of the regression line was *negative*, indicating that the lower-ability children benefited relatively more from maternal responsivity. By the age of 48 months, the regression slope had reversed and become *positive*, meaning that higher-ability children became even more capable given high-quality interaction with their mothers. Thus, high-quality mother-child interaction seemed to have a compensatory function early on, but later had a cumulative advantage function, serving to make initial differences even greater. These findings were not simply an epiphenomenal product of shared mother-child genotype because they were detected in both biological and adopted children.

Research by Sigel and his colleagues likewise demonstrated a connection between patterns of parent-child interaction and cognitive development (Sigel et al., 1993). When parents adopt high-level distancing strategies—sociolinguistic patterns that encourage open-ended thinking and transcendence of immediate experience—their children typically have higher levels of cognitive ability and academic achievement. By initiating *distancing acts*, parents foster cognitive competence in their children, including the ability to see differing symbolic structures as pointing to the same physical referent, or what Sigel called *representational competence* (Sigel, 1993; Sigel, Anderson, & Shapiro, 1966). Cognitive distancing, symbol-referent identity, and the equivalence of symbols are much the substance of formal education, and all likely to be central elements of the developing intelligence repertoire.[2]

Socioeconomic Status

Socioeconomic status (SES) is a powerful construct for understanding differences in social behavior, social standing, and social mobility. It is also a powerful predictor of life paths. It is well known, for example, that family socioeconomic background exerts long-term effects on measures of adult success, including educational and career attainments (Bowles & Nelson, 1974). Positive correlations

between socioeconomic status (SES) and cognitive outcomes have long been recognized (Joffe, 1982; Stoddard & Wellman, 1940). Values, expectations, childrearing practices, and other qualities of family life associated with SES may impact cognitive outcomes directly. In fact, Davis and Havighurst (1946) construed SES *in terms of* its cognitive implications: "The pivotal meaning of social class to students of human development is that it defines and systematizes different learning environments for children of different classes" (p. 699). Spaeth's (1976) path-analytic model likewise accounts for the effects of parents' SES on children's IQ entirely in terms of cognitive socialization, manifest as environmental complexity, within the family.

As a global variable, SES summarizes a collection of more functionally active variables, such as parents' education level and occupation, and family income. It is these more proximal variables that are potentially causal in growing and shaping a child's cognitive repertoire. Parents' education level especially is a potent differentiator of high- and low-achieving children. In nationally representative data sets, both mothers' and fathers' education levels constituted the strongest family-demographic predictors of a children's academic achievement (Grissmer, Williamson, Kirby, & Berends, 1998). The effect of a parent's college education versus noncompletion of high school amounted to more than one standard deviation in children's mathematics scores, or about one half standard deviation when controlling for other factors such as income. Parents' education is *not* a mere proxy for genetic characteristics shared across generations. Adopted children whose biological mothers had less than a high school education were sensitive to the educational level attained by their adoptive mother. Differences in the educational attainment of the adoptive mother can account for about one half standard deviation in the IQs of adopted children (Scarr & Weinberg, 1983).

Again, effects associated with SES or parents' education must be exercised through variables that are more proximal to the child's experience. Patterns of language use are especially notable, because language shapes what aspects of the environment and internal thoughts and emotions are worth attending to (Bernstein, 1961). Sentence syntax can constrain or liberate a child's capacity to combine ideas flexibly. Patterns of language use have their origin in the style of communication between parents and children. Mothers with no formal education tend not to ask "known-answer" questions (a basic convention of mental tests and schooling) of their children, whereas mothers who have even minimal exposure to schooling can mimic teacher behavior by asking such questions (Greenfield, 1998). Parents also differ in the quality of answers they provide to their children's questions: High-SES parents tend to supply more elaborate responses to questions asked by their children (Sternberg, 1994a), and in general have richer verbal interactions with them (Hart & Risley, 1995). High SES parents also tend to be less directive of their children's behavior, are more likely to see their children as being independently motivated, and are more likely to communicate with their children in a positive affective tone (Jennings & Connors, 1989).

SES-related patterns of parent-child interaction are associated with children's cognitive development. Hart and Risley (1995) found that children's verbal abilities and measured IQ were strongly related to patterns of verbal interaction between parents and children, even when variance associated with SES was removed. Positive affective tone (e.g., praise, encouragement) has repeatedly been found to mediate SES and children's verbal ability, presumably because it establishes a safe and inviting environment for children to experiment with verbalizing their thoughts and questions (Jennings & Connors, 1989). Low-SES mothers tend instead to be directive in their children's play, a pattern negatively associated with nonverbal (or fluid) competency, even when SES is partialled out. High directiveness is probably a general parenting style and not just reactive to children's need for assistance; this style of parental control is asserted soon after tasks are presented and is exhibited even in open-ended play (Jennings & Connors, 1989).

Middle-class home life tends to be flexibly structured, adopting a middling path between the extremes of weak structure in which activities lack regularity, and rigid structure in which behavior patterns are strictly enforced. A flexibly structured home exhibits regularities (such as a default "bedtime"), but allows for exceptions given certain contingencies (like a weekend). Tension between the familiar and perturbation of the familiar has been hypothesized to elicit the Piagetian mechanisms of disequilibrium followed by equilibration through the formation of new schemes, and therefore to cognitive advancement. Statistically, flexible home structures have been associated with higher-level Piagetian task performance and with higher levels of academic achievement (Ogilvy, 1990). Like other parenting variables described earlier, home structure is also associated with SES, but its instrumental utility is evident in that it predicts cognitive outcomes even when variance from SES is controlled (Ogilvy, 1990).

Adoption studies constitute another stream of evidence showing that environmental factors associated with SES are instrumental in cognitive development (Locurto, 1990). Children who are adopted into high-SES families tend to have higher IQs than do similar children reared by their birth mothers (Neisser et al., 1996; Scarr & Weinberg, 1983), although their IQs are usually not as high as those of their nonadopted siblings (Locurto, 1990). The reactivity of IQ to SES is most clearly demonstrated in adoption studies that feature highly contrasting environments, in which the SES of the biological and adopting families differ markedly. Locurto's (1990) rather conservative analysis of cross-SES adoption effects led to the conclusion that the average IQ of adopted children was around 106, which was about 10 to 12 points higher than it would have been had those same children not been adopted.

One of the better-known studies of cross-SES adoption is the French Adoption Study (Dumaret, 1985). In this study, children of low-SES mothers were adopted into "privileged" families before the age of 7 months. Dumaret contrasted these children with their full- and half-siblings who where raised by their biological mothers or by close relatives, and with siblings who were raised in foster or group

homes. The three groups were compared on measures of IQ, school achievement, and social adjustment. The groups differed markedly, with higher IQs and academic achievement associated with children adopted into high-SES homes. On the full Wechsler Intelligence Scale for Children (WISC), the mean IQ for the adopted children was 109.2, whereas siblings raised by biological relatives had a mean IQ of 93.0, and foster/group home children had a mean IQ of 80.8 (all differences, $p < .002$). The three groups also differed in academic success: Adopted children had very few instances of grade repeats or of leaving school, and were more often rated as "gifted" by their teachers. Among children in the other two groups, academic failure and behavior problems were common. It is notable that comparison siblings who were raised in emotionally stable biological families—that is, in homes not characterized by conflict and disharmony—tended to have fewer behavior difficulties and higher IQs than comparison siblings raised in dysfunctional homes.

A more recent investigation, the French Cross-Fostering study, is unique in its four-group design, formed by crossing high- and low-SES biological families with high- and low-SES adoptive families (Capron & Duyme, 1989). This design permits examination of the adoption effects of moving *up* in SES, and of moving *down*. Although the sample size was smallish (total N = 38), the study had the technical advantage of equating children on possible confounding factors, such as birthweight, age at adoption, and the prevalence of perinatal complications. In this study, there was no evidence of selective placement or influence of attrition. IQ testing using the WISC-R was performed by psychologists who were uninformed as to the nature of the study.

The main effects of the study are presented in Table 8.2. The table displays independent effects, both of a comparable magnitude, for the SES of biological parents and for the SES of adoptive families. Placement in high-SES adoptive families was associated with a positive effect of 12 IQ points, and this effect held

TABLE 8.2
Cross-SES Adoption and IQ

	SES of Adoptive Parents					
	High			*Low*		
SES of Biological Parents	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*
High	10	119.6	12.25	8	107.5	11.94
Low	10	103.6	12.71	10	92.4	5.41

Note. From "Assessment of Effects of Socio-Economic Status on IQ in a Full Cross-Fostering Study," by C. Capron and M. Duyme, 1989, *Nature, 340,* p 553. Adapted by permission from *Nature.* Copyright 1989 by MacMillan Magazines Ltd.

for children of high-SES and low-SES biological parents. The *detrimental* effects of placing the child of high-SES biological parents into a low-SES family is likewise about 12 points. Nonetheless, the SES of biological parents also had an effect, accounting for about 15 IQ points. The interpretation of this latter effect, however, is not entirely clear. Although the "effect attributable to adoptive parents is clearly environmental," the study was "not equipped to differentiate prenatal from genetic factors" (Capron & Duyme, 1989, p. 553). The effect associated with biological parents could be attributable to either or both factors, or to their interaction.

Not all adoption studies have found comparable effects of SES on the IQs of adopted children. The Texas Adoption Project, for example, demonstrated an effect of only about 1.5 IQ points, which was not significant (Loehlin, Horn, & Willerman, 1997). In this study, however, adopting parents were restricted in range in both SES and IQ, with "high-SES" and "low-SES" groups formed by a median-split procedure, and thus this sample might have underestimated cross-SES adoption effects. Even in studies that do show SES effects, the exact influence of SES remains unclear, primarily because it is difficult to disentangle genetic factors from experiential factors. Resources in the home and parental language patterns are both related to children's IQ, but it is possible that both resources and language patterns are mediated by parents' IQ, which is in turn reflects (to some degree) parental genotype. There is, however, evidence for *independent* effects of home environment on cognitive development, even when maternal IQ is partialled out (Gottfried, 1984).

Despite the importance of the home environment, family influences, over time, tend to be overshadowed by differences in individual life experience—and by genetic factors (Neisser et al., 1996). Peer cultures also play a strong role in development (Harris, 1995), and may be an important channel for the propagation of values and beliefs associated with socioeconomic status. For the adolescent, part of growing up means managing a set of expanding life options, and the resulting unique decision chain weakens the long-range effects exerted by the early childhood environment established by parents. As Scarr (1997) noted, "The everyday world for most people consists of choices about what to listen to and look at, what to ignore, where to be and with whom" (p. 37). At these choice points, genetic differences apparently reassert themselves. Even so, gene-related niche building occurs only through different *experiential* paths, and by any logic these paths must be contingent on the array of available options. Whether genes or experience has primacy is not immediately clear, nor is it clear that attempts to parcel effects into these two sources is meaningful (Bidell & Fischer, 1997).

The relationships between experience and cognitive growth are important, but they are not simple. Functional relationships between such variables as parent-child interactional style and cognitive development vary according to the particular culture in which the child is raised. The complexity of environmental influences on cognitive development is illustrated by the finding that both parent-child interactional patterns and nutrition affect cognitive development, but not additively

or independently. For example, the quality of caregiving by adults can be influenced by a child's nutritional status (Chávez & Martínez, 1975; Pollitt, Gorman, Engle, Martorell, & Rivera, 1993; Wachs, 1993). The interactions are also multiplicative, in that the combined effect of poor nutrition and poor caregiving is larger than the sum of the effects of either variable in isolation. This also means that if one variable has a positive valence—if the child receives either good nutrition or competent caregiving—this one variable has buffering effects that attenuate the deleterious consequences of the other. Similarly, a cognitively enriched preschool experience can buffer the effects of "nonoptimal" Apgar status at birth on later cognitive performance (Breitmayer & Ramey, 1986).

These examples demonstrate that the relationship between a child's experience and cognitive development is not always reducible to a nomothetic, stable, and transportable pattern, but is often mediated by cultural, subcultural, and sociodemographic contextual variables (Wachs, 1996). Thus, the complexity that laces social phenomena generally applies to cognitive development. Straightforward laws connecting experiential input and cognitive output are elusive. Instead, undercomplicated main effects give way to the disorienting reality of complex interactions—Cronbach's (1975, p. 119) "hall of mirrors that extends to infinity"—in which the relationship between two variables depends on a third variable, and that three-way pattern depends in turn on a fourth variable, a fifth, and so on.

SCHOOL EXPERIENCE

The association between IQ and amount of formal education is impressive—correlations range from about 0.50 to 0.90 (Ceci & Williams, 1997). Perhaps the most ready interpretation of this association is that schooling provides incentives for those who have more native cognitive ability to pursue higher levels of education. By this account, intelligence is the driving force leading to higher levels of educational attainment, better jobs, and higher pay. However, there is another possibility—that education actually promotes the growth of intelligence (Ceci & Williams, 1997). These explanations are not necessarily contradictory: Causal influence may be bidirectional. But because the hypothetical role of education on the cultivation of intelligence is much less appreciated or even recognized as a possibility, evidence for effects in the education-to-intelligence direction are presented in this section.

Contrasts of WWI and WWII American Soldiers

Although Flynn (1987, 1998) is credited with compiling and synthesizing evidence pointing to a rather abrupt, large-scale, and perhaps global rise in IQ, he was not the first to discover data of this kind, nor the first to suggest the possibility (e.g., Wheeler, 1970/1942). In 1948, Tuddenham documented increases in IQ among American soldiers between WWI and WWII. Tuddenham showed that between 1917 and 1942 the mean IQ of men who enlisted or were drafted into the U.S. Army rose about one standard deviation. The increase had observable effects. According to Humphreys (1989), the jump in IQ was manifest functionally in that "the average 18-year-old in 1942 was able to learn general military and specialty skills more quickly than his counterpart in 1917" (p. 198). Humphreys attributed the intergenerational IQ gain to an increase in the average number of years of schooling during the intervening period. Between the wars, the mean duration of schooling for American males rose from about 9 years to about 12 years. These 3 additional years of schooling in later adolescence might have afforded WWII soldiers a greater opportunity to study material that was more abstract, complex, and demanding than was possible at younger ages (cf. findings by Husén, 1951).[3]

English Canal Boat Children

Several studies converge to support the causal association between amount of formal education and IQ (e.g., Loehlin, Lindzey, & Spuhler, 1975; Teasdale & Owen, 1987; Vernon, 1948). One example is Gordon's (1970/1923) study of the intellectual characteristics of English canal boat children. Gordon's original report, published as a government pamphlet in 1923, described canal boat families as spending most of their lives ferrying cargo along the waterways of Great Britain. Their itinerant lifestyle meant that children in these families had little exposure to formal education. Even though the government had established special schools for canal boat children, their families were so transient that the children attended school fewer than 10 days each year, on average. Canal boat children were in general healthy, clean, well clothed, and well mannered, and yet their average Stanford-Binet IQ and "EQ" (educational quotient, based on achievement in reading and arithmetic) were both approximately 70 (and correlated 0.72, N = 36), which by traditional criteria would put them in the borderline retarded range.

More telling than average IQ was the tendency of IQ scores to decline with age. The steady downward trend is depicted in Fig. 8.1. The graph displays data from the subset of Gordon's sample of families that had at least two school-age children, a reduced sample that provides some measure of control over possible environmental and genetic confounds. The graph shows that although the youngest children had IQs that were near normal, the mean IQ for firstborn children was around 60 (N = 76). So strong was the downward trend that the age-IQ correlation was robustly negative ($r = -0.76$). Gordon noted that cognitive development tended to rise during the preschool years and then flattened out, such that school-age siblings, regardless of age, typically had a mental age of about 6 or 7 years.[4] From these observations, Gordon concluded that the retardation of canal boat children was "not due to heredity, seeing that the youngest children test more or less

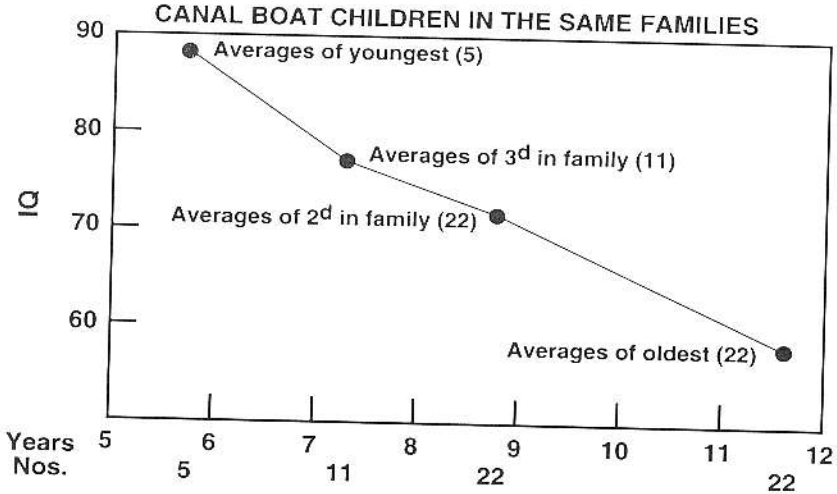


FIG. 8.1. Decline of IQ with age among canal boat children. From "The Intelligence of English Canal Boat Children," by H. Gordon, 1970. In Cross Cultural Studies of Behavior (p. 117) by I. Al-Issa and W. Dennis (Eds.). New York: Holt, Rinehart and Winston, Inc. Originally appearing in Mental and Scholastic Tests Among Retarded Children, Educational Pamphlet, No. 44. London: Board of Education. Copyright 1923 by Her Brittanic Majesty's Stationery Office. Reprinted with permission.

normally," and inferred "with some reasonableness that the lack of schooling has affected both 'mental' and scholastic attainments to the same extent" (Gordon, 1970, p. 119).

IQ and Amount of Schooling: United States

Binet's original IQ test was designed to predict school attainment; however, the relationship also works in the reverse—school attainment can predict IQ. Working with adult subjects, Lorge (1945) compared intelligence test scores for 130 men at ages 14 and 34. Across the sample, correlations between IQ scores at age 14 and age 34 were 0.64 for the Otis and 0.62 for the Thorndike scales. The more impressive finding is that when subjects were blocked according to their IQ at age 14, IQ scores on the later-administered Otis and Thorndike scales rose as a function of the highest grade completed. The association of IQ with education is again evident when the data are examined another way. The correlation of IQ at age 14 with the amount of formal education eventually completed is 0.36, showing that adolescent IQ can predict later academic achievement, but only modestly. However, the correlations between education and IQ at age 34 were much larger—0.67 for the Otis and 0.68 for the Thorndike—even though the later IQ scores were more distal in time from schooling and obtained *after* formal education was completed (cf. Husén and Tuijnman, 1991, for a corroborative finding).

When the two sets of correlations are squared to reflect variance accounted for, the plausible effects of schooling on IQ are clearer still. IQ measured at age 14 accounts for about 13% of later variation in educational achievement, but educational achievement can account for about 45% of the variation in adult IQ. In other words, IQ does predict educational attainment, but educational attainment predicts subsequent IQ even more. This implies is that the relationship between intelligence in education is one version of the chicken-and-egg problem. Snow (1982a, 1982b) described intelligence as both a raw material for education and a product of education. Which has primacy? Most take for granted the idea of intelligence as raw material. Lorge's data hint that the characterization of *intelligence* as *product* is also to be taken seriously. His conclusion was unequivocal: "Schooling, therefore, makes a difference in the intelligence score that an adult will obtain" (Lorge, 1945, p. 489).

IQ and Amount of Schooling: Sweden

Lorge's findings were corroborated by Husén's (1951) study of schooling and IQ change. Husén's subjects were 722 boys born in 1928 in Malmö, Sweden. IQ scores were obtained when the cohort was 10 years old and again at age 20. During the intervening 10 years, subjects' educational paths diverged, their attainment ranging from completion of primary school (Grade 7) to matriculation from senior secondary school (Grade 12 or 13). Table 8.3 summarizes Husén's findings. IQ gains increased monotonically as the level of schooling rose, with gains for three highest-attaining groups deviating significantly from zero. The increase is not linear, but accelerates at the higher grades of secondary school—an effect Husén associated with the more theoretical character of subjects in the higher grades. Because the three highest groupings did not differ significantly in initial IQ, their divergence in IQ gains cannot be attributed to different starting points.

TABLE 8.3
Effects of Schooling on IQ Change—Malmö, Sweden

Level of Schooling Completed	*N*	*Grades Completed*	*Mean IQ Change*	*Percentage of Subjects With Increased Scores*
Primary School	431	7	-1.18	46.2
Junior Secondary (no cert.)	28	7-10	2.07	53.6
Junior Secondary (cert.)	73	9-10	2.99	63.0
Senior Secondary (no cert.)	66	11-13	7.23	77.3
Matriculation	15	12-13	11.03	86.7

Note. From "The Influence of Schooling Upon IQ," by T. Husén, 1951, *Theoria, 17,* p. 71. The Copyright 1951 by the Swedish Council for Humanistic and Social Science Research. Adapted with permission. Abbreviations *cert.* and *no cert.* refer, respectively, to the attainment of a school leaving certificate or not.

When Husén's (1951) subjects were blocked by initial IQ, educational attainment was found to be related to subsequent IQ, just as in Lorge's (1945) study. Within IQ blocks, Husén found that IQ gains associated with a junior secondary school certificate (Grade 10) were 6 to 14 points higher than the IQ gains of those who completed primary school only (Grade 7). Moreover, Husén found that the effects of social variables, including family income, were much smaller (about 3 IQ points for the highest income groups) than schooling effects on adult IQ. On the basis of this analysis, Husén (1951) concluded that schooling "has incomparably the greatest significance for the systematic changes in IQ between 10 and 20 years of age" (p. 71). Härnqvist (1959, cited in Härnqvist, 1968) later reanalyzed Husén's data by regressing follow-up scores on original scores, rather than simply computing gains, and found somewhat smaller IQ gains associated with schooling. Decades later, Husén and Tuijnman (1991) analyzed the Malmö data once again, this time using multivariate path analysis procedures. The analysis confirmed a direct effect of educational attainment on adult IQ, independent of home background and IQ at age 10.

Härnqvist (1968) conducted a comparable study of the effects of education on IQ, also in Sweden. Subjects constituted roughly 10% of the Swedish population of boys born in 1948. IQ was assessed in 1961, when subjects were 13 years old, and again in 1966 at age 18 (N = 4,616). Regression analyses showed that IQ drift over the intertest period was a function of the level of education attained. Those who had received more formal education experienced an upward IQ increment corresponding to an effect size of +0.34, and those who received less education experienced a downward drift of -0.21. The "distance" between the higher group and the lower group corresponded to an effect size of 0.55, or about 8 IQ points, which is somewhat lower than that found by Husén but still appreciable.

Härnqvist found a slightly larger effect when he contrasted groups that were more extreme in educational experience. When students were separated into those who completed only compulsory school (up to Grade 8) and those who received some education in the *gymnasium* (a university preparatory school), IQ drift distance amounted to 10 IQ points. Härnqvist explored the possible contribution of home environment to IQ shift, and found that such factors as parents' education and occupation, as well as municipality of residence, contributed somewhat to the magnitude and direction of IQ drift. The schooling effect was only slightly diminished in magnitude when home environment was "controlled" by comparing educational effects within five strata of home "background level." However, when students were compared within the five strata of educational experience, the prediction of IQ change from home background was weak.

Härnqvist's study was replicated and expanded by Balke-Aurell (1982), who examined yet another Swedish cohort, born in 1952. Again in this study, extent of education predicted shifts in IQ between the ages of 13 and 18. The magnitude of the shifts, over the spectrum of educational experience, was slightly greater than one half of the pooled standard deviation of IQ. Beyond this main effect, Balke-Aurell found that subjects' *profiles* of cognitive abilities were sensitive to educational and occupational experience. In particular, technical (including scientific and mechanical) education and job experience enhanced spatial/technical abilities, whereas verbally oriented education and job experience enhanced verbal abilities. Initial verbal-spatial ability profiles also predicted the choice of field of study. These data therefore show that cognitive ability profiles *influence* and are *influenced* by subsequent experience, much as general intelligence predicts educational experience and is also shaped by it.

Wartime Disruption of Schooling

De Groot studied how the disruption of schooling in Holland during World War II affected the cognitive abilities of children (de Groot, 1948, 1951). Between 1941 and 1944, Eindhoven, Holland, was occupied by the German army and was later garrisoned as a Nazi military center. Residents of Eindhoven suffered severe disruption of their lives during that period as they faced air attacks, a lack of transport and fuel supplies, and the commandeering of their schools and other facilities. Also during that time, many adult males, including teachers, went into hiding, and schools were closed intermittently. Even when schools were in session, truancy was a serious problem. The situation grew worse: In September 1944, Eindhoven was at the front lines of battle, and even after its liberation the disruption continued as Eindhoven became a transit center for Allied troops. De Groot calculated that partial or complete school closures put school-age children in arrears by about a year and a half.

De Groot wanted to know if the disruption of schooling affected local children's IQ. To find out, he examined test scores for applicants to the Philips Industrial Training School in Eindhoven. The applicants were boys whose average age was approximately 13 years, 6 months. The Philips entry test battery included a Dutch translation of the American National Intelligence Tests. De Groot found that during the prewar period from 1938 to 1943, applicants' test scores hovered close to 100—the expected mean. Between 1944 and 1948, near the climax of the war and its aftermath, the mean IQ dropped 4 to 5 points. Later, in 1949 and 1950, scores returned to their prewar levels. Both downward and upward shifts were statistically significant. The data suggest, but do not prove, the instrumentality of formal education in inculcating the cognitive skills measured by IQ tests. Other factors could have contributed to the effect: Notably, the co-occurrence of war and the disruption of schooling complicates the interpretation of IQ changes over time. At the very least, according to de Groot, the Eindhoven data show that intelligence should not be regarded as an innate and immutable entity, but as a product of experience.

Public School Closure in Virginia

In the United States, the effect of schooling disruption on IQ was demonstrated during a study of school shutdowns in the Civil Rights Era. The shutdowns were not precipitated by war per se, but by the desegregation of schooling mandated in *Brown v. Board of Education* (1954). Following *Brown*, the Board of Supervisors of Prince Edward County of Virginia resisted integration and eventually closed all public schools in the county between the spring of 1959 and the fall of 1963 (Green, Hofmann, Morse, Hayes, & Morgan, 1964). During that period, the education of White students was maintained through the establishment of the Prince Edward School Corporation, which opened all-White private schools in September 1959. These actions left 1,700 Black children without any formal provision for their educational needs for 4 years.

In response to this dire situation, leaders in the Black community arranged for short-term educational experiences, such as summer "crash" programs, to help compensate for lost time in classrooms. Those students who participated in the compensatory programs received, on average, the equivalent of 1.5 to 2 years of schooling during the 4-year period. In a study of the shutdown effects, these students were collectively called the EDUCATION group (N = 150); those who received no compensatory experience were labeled the NO EDUCATION group (N = 138). Cross-sectional analysis of subsequent Stanford-Binet scores show that mean IQs in both groups dropped about 15 points during the years of school closure, although the data show higher overall IQs for the EDUCATION group. The results are somewhat complicated by the fact that the EDUCATION and NO EDUCATION groups were probably not strictly comparable in initial IQ and family background, and the sample sizes at each grade level were small, generally less than 20 students. Nonetheless, the dramatic fall of IQ in both groups during this period reinforces the proposal that depriving children of educational opportunity can have deleterious effects on their general cognitive growth.

Grade Acceleration and Delay

In the school-age population, children within each grade are approximately the same age, but of course not exactly. Cahan and Cohen (1989) took advantage of this fact when they compared the educational achievement of students whose school experience differed as a consequence of the arbitrary cutoff dates for school entrance. The research design permitted comparisons between students of similar chronological ages, but who differed experientially by 1 year of schooling. The study involved approximately 10,000 fourth-, fifth-, and sixth-grade students in Jerusalem schools. Using a between-grades regression analysis, the investigators assessed the independent contributions of maturation (chronological age) and schooling to performance on 12 tests of cognitive ability. They addressed the possible confounds of grade acceleration (with giftedness) and delay (with learning problems) by eliminating from their sample students born in November and December (the months nearest the cutoff date).

The most impressive finding was that the effects of schooling were more powerful than the effects of chronological age on all tests of cognitive ability, and on most tests the schooling effect was about twice that of maturation. According to Cahan and Cohen (1989), the results point to schooling as "the major factor underlying the increase in intelligence tests scores as a function of age" (p. 1245). The effects of schooling differed in magnitude across tests, exerting a stronger influence on tests of crystallized abilities, such as verbal and numerical ability, and a weaker effect on tests of nonverbal fluid abilities, such as figural analogies. Nevertheless, the independent effect of schooling on fluid abilities is significant theoretically, because it challenges the idea that fluid intelligence is developed indirectly (Cronbach, 1984). More generally, the study by Cahan and Cohen (1989) points to the "critical contribution of formal education" to the development of intelligence (p. 1247).

A study conducted in South Africa's Natal province also found substantial correlations between IQ, including fluid intelligence, and variation in years of schooling as a result of delayed entry (Schmidt, 1960). The schooling effects were independent of the chronological age and the SES of students. The research focused on the Indian population, which at the time of the study could not be fully accommodated into schools because of an insufficient number of teachers and classrooms. As a result, Indian children entered school sometime between the ages of 6 and 10, whenever space became available. In a sample of more than 200 13-year-old students, an impressive correlation was obtained between years of schooling and performance on Raven's Progressive Matrices ($r = 0.51$), and the correlation of school experience with verbal ability was even stronger ($r = 0.68$). When data were analyzed across grades, raw scores on Raven's Matrices were almost identical for younger "early starters" and for older "late starters"—that is, fluid intelligence as measured by Raven's seemed to be a function of amount of schooling rather than chronological age. The study's author concluded that schooling is "the decisive factor" in the development of verbal (crystallized) and non-verbal (fluid) intelligence (Schmidt, 1960, p. 429).

Summer Vacation

The suspension of schooling during the summer months (i.e., summer vacation) has been found to impact learning rates, and to do so differentially according to children's economic and racial/ethnic backgrounds. Hayes and Grether (1983) documented this effect from data collected in the mid-1960s. The investigators divided New York City public schools into six groups according to their racial composition (percentage White) and socioeconomic characteristics (percentage of children receiving a free lunch). Employing a cross-sectional design spanning Grades 2 through 6, the authors examined changes in reading achievement and

word knowledge on the basis of twice-yearly examinations conducted in early fall and late spring. With these data, they were able to separate the effects of summertime and school-year experience on achievement outcomes. Hayes and Grether (1983) found that, by the end of sixth grade, the gains in reading achievement made by the richer White schools were 2 years greater than the gains made by the poorer minority schools. However, only half of this difference could be accounted for by gains made during the school year; the other half represented differential gains made mostly during the summer months when school was not in session. "Put another way," said the authors (1983, p. 60), "the four summers between the 2nd and 6th grades produce a reading differential almost equal to the effects of five academic years."

The effect of summertime experience on word knowledge was even more dramatic. Very little of the group difference in word knowledge was the product of school experience; most of the differential gain occurred during the summer months. Between the two groups representing the poles of the economic continuum (and, in this sample, groups defined by race), school-year effects were responsible for about a 6-month differential in word knowledge by the end of sixth grade. By contrast, the summer vacation months were associated with a differential gain of a full 2 years. For the poorest children, summer vacation was academically unproductive; gains in reading achievement and word knowledge slowed dramatically, plateaued, or even regressed. Students from wealthier families, however, made substantial achievement gains during the summer. Word knowledge advanced as if nonschool experiences provided much the same cognitive stimulation as did schools, and so maintained a cognitive growth trajectory that was comparable to that achieved during the school year. In other words, for the wealthier children experience of high educative quality was continuous, whereas for the poorer children it was interrupted.

A later study by Heyns (1978) identified some of the nonschool activities that might account for group differences in rates of achievement during the summer months. In findings that paralleled the earlier study by Hayes and Grether, Heyns found that low-SES Black children in Atlanta lost ground in comparison to White students in both relative and absolute levels of academic achievement. In general, high-SES White children had freer access to summer activities that enriched intellectual development. These activities included using the library, going on vacation, and even having a bicycle—all were associated with the larger separation of Black and White learning trajectories during the summer months.

Data demonstrating the educative or noneducative effects of summer experience reinforce the assertion that the term *education* must embrace all forms of experience that have cognitive value, not just the formal apparatus of schooling (Brandwein, 1981). Potent differences in nonschool educational experience certainly extend to the preschool years. However, data on the effects of summer vacation show that, even during the school years, nonschool experiences play a major role in producing

and sustaining differential rates of intellectual development. On this point, Hayes and Grether (1983) were direct: "In short, very little of the enormous difference in word knowledge performance of ghetto and relatively rich whites found by the end of 6th grade appears to be attributable to what goes on *in* school; most of it comes from what goes on *out* of school" (p. 64; emphasis in original).

On the basis of their findings, Hayes and Grether (1983) questioned the wisdom of placing hope in the institution of schooling for redressing social inequities. Citing the Coleman Report (Coleman et al., 1966), they reminded the reader that much of the variation in students' academic achievement is a product of nonschool factors, and therefore "not . . . under the direct control of teachers, principals, or school boards" (Hayes & Grether, 1983, p. 66). This is not to say that schools are ineffectual or irrelevant in redressing racial/ethnic and socioeconomic differences in academic achievement. On the contrary, schooling acts as a buffer to reduce differences in the slopes of academic achievement rates (Heyns, 1978). In this sense, schooling is a powerful institution for correcting social inequities. Yet, the potency of nonschool educational experiences makes it clear that it is unrealistic to expect schools to erase all differences between groups in cognitive outcomes. To advance the cause of equity and to promote the fuller realization of potential for all, it is imperative to understand that although schooling is a major instrument for cognitive development, education is accomplished through a far broader array of experiences.

Cross-Cultural Effects of Schooling

Effects of schooling on intelligence have been observed in countries making the transition toward compulsory universal education. Stevenson, Parker, Wilkinson, Bonnevaux, and Gonzalez (1978) examined the effects of schooling on cognitive task performance among selected subpopulations of Peru. The subpopulations were defined by three cultural groups (Mestizo, Quechua Indian, and "upper middle class"), by two locations (urban Lima and jungle Lamas), and by two levels of school experience (first-grade attendance and nonattendance). The investigators found that even a single year of school attendance affected performance on all cognitive tasks they employed, including memory tasks (e.g., serial words, serial numbers, pictorial) and cognitive tasks (e.g., concept learning, categories, seriation). Mean differences in cognitive performance were also found along cultural and location dimensions of comparison, but the effects of schooling were stronger and comparable among all subgroups. Commenting on this study, Greenfield (1978) pointed out that the main effects of schooling are often overlooked by those who expect school experience to reduce group and individual differences. She reminded the reader that "schooling may have a tremendous impact on cognitive performance independent of its capacity to erase group differences" (pp. 84-85).

Quality of Schooling

If differences in exposure to or quantity of schooling influence cognitive development, so might differences in the *quality* of schooling. According to the cumulative deficit hypothesis, when the quality of schooling is very poor, student IQ scores could actually drift downward over time. Jensen (1977) proposed that data supporting the hypothesis would be obtained if, within families, older siblings tended to have lower IQs than younger siblings, and if the younger-older IQ gap widened as age differences between siblings increased.[5] Jensen failed to find support for the cumulative deficit hypothesis in predominantly Black California schools, but later examined data from comparable schools in rural Georgia, where between-race differences in the quality of schooling were much more severe. Jensen reasoned that if evidence for the cumulative deficit hypothesis could not be found in rural Georgia, it probably could not be found anywhere in the United States.

In Georgia, Jensen did indeed find data supporting the cumulative deficit hypothesis. Among Black students between the ages of 6 and 16, cognitive decline amounted to a linear decrement of 1.42 IQ points per year, which is equivalent to a loss of about 15 points, or one standard deviation, over the course of schooling. Jensen tested the possibility that other factors contributed to this effect, but found that birth order was irrelevant to the IQ decrement, and that family size contributed to it only marginally. Jensen speculated that genetic factors might be responsible, in whole or part, for the IQ decrement by placing limits on the growth curve of *g* among Black students. The data, however, did not support this interpretation because IQ decrements comparable to those found in Georgia were not observed in the less severely deficient schools in California. Jensen (1977) concluded that the contrast between California and Georgia schools "would seem to favor an environmental interpretation of the progressive IQ decrement" (p. 190).

Summary of Schooling Effects

The idea that formal education contributes directly to the formation of intelligence was expressed plainly by Stephenson, who in 1949 "made a passionate plea for recognizing the role of *the school itself* in developing (in a sense even *creating*) the intelligence of the child" (Schmidt, 1960, p. 416). Data bearing on the connection between schooling and the growth of intelligence is primarily correlational, but it is nonetheless convergent. After reviewing eight strands of evidence linking IQ enhancement to schooling, Ceci (1991) concluded that "the most parsimonious account of the correlations that have been reviewed is a direct causal link" (p. 711), an attribution that Carroll (1997, p. 42) called "only too obvious."

Still, the linkage between schooling and intelligence is understood only imperfectly. One problem is that the institutionalized covariation of maturation and schooling in modern societies makes it difficult to separate the independent effects of each. However, with the proper analytic tools they can be disentangled, and in at least one study the effects of schooling on IQ were found to be larger than the effects of maturation (Cahan & Cohen, 1989). This and similar other findings point to a more complex relationship between education and intelligence than is generally recognized. Almost universally, intelligence is thought of as preparatory for education. Intelligence does have that function—as "input"—but it is more. Intelligence is also, in part, an output or product of schooling, but it is so unwittingly. That schooling raises intelligence is, in terms of the stated purposes of schooling, an accident. Intelligence is a by-product. Even if educational institutions have not recognized their role in boosting the intelligence of billions of students in the 20th century, society has come to depend on the intelligence by-product. Society's expectations for and definition of an educated person include the ability to think intensively and flexibly about complex matters in the course of finding and solving significant problems. What schools supply incidentally, society demands insistently and consumes voraciously.

What is incidental can become intentional, and what is by-product can become main product. A recognition of schooling's ability to raise general cognitive preparedness can be used as a basis for restating the function of schooling to embrace the equipping of learners with the most general and powerful of intellectual abilities, intelligence. Of course, schooling is not the only mechanism by which intelligence is grown, and schools are not solely responsible for ensuring the intellectual readiness of future citizens. Schools have never had a monopoly in the business of cognitive development. But in the future schooling can play a critical role in the development of intelligence, just as it has in the past. An explicit adoption of that purpose could lead to even greater effectiveness of schools in making people smarter.

UNIVERSITY EXPERIENCE

For many people, collegiate education is a life phase associated strongly with gains in cognitive abilities, knowledge, and skills. Research synthesized by Pascarella and Terenzini (1991) quantified such gains in formal (abstract) reasoning (effect size approximately 0.33 SD), critical thinking (1.0 SD), ill-structured problem solving (1.0 SD), and the ability to deal with conceptual complexity (1.2 SD). These effects, converted to an IQ scale, suggest that the college experience can produce gains ranging from 5 to 15 points. The research showed that the nature of the cognitive boost is complex: Students improved their ability to weigh evidence and to judge inferences from data, but not necessarily their ability to recognize assumptions or to deduce conclusions from premises. Moreover, the authors were clear that only a portion of the cognitive gains could be directly attributed to the college experience. However, the gains were not illusory: They held up even when possible confounding influences, such as SES and initial intellectual ability, were controlled.

Why should a college education enhance cognitive development? Although the answer is not definitely known, Pascarella and Terenzini (1991) suggested a reasonable explanation: "Of all the experiences a student could have after secondary school, college is the one that most typically provides an overall environment where the potential for intellectual growth is maximized" (p. 156). In the university several potent agents of intellectual enhancement—faculty, students, libraries, and laboratories—are "concentrated in one place" (p. 156). Whatever effects a university education may have on cognition, ancillary effects also result. A university experience can influence the tastes, interests, grammar, and accent of graduates (Herrnstein & Murray, 1994). Many of these acquired characteristics have no direct adaptive value, but instead are signs of privilege and perhaps credentials for further opportunity, a point enlarged on by Hirsh (1987) in his construct of cultural literacy.

College has important short-term effects on students, but the long-term consequences of a college education on subsequent generations may be even more important. Children of college graduates are poised for higher educational attainment, occupational status, and income than are children of parents who did not graduate from college, even when possibly confounding factors (family income, intelligence, aspirations, race, and gender) are controlled (Pascarella & Terenzini, 1991). However, the "confounding" variables are themselves important: The intervening variables of family income and aspirations have instrumental value in the educational and career attainments of children.

Another likely influence pathway is the effect of college on parenting style (Pascarella & Terenzini, 1991). College-educated parents, mothers especially, spend relatively more time with their children on activities that advance cognitive development (e.g., reading, teaching). Even within socioeconomic groups, the level of education attained by a mother is correlated with qualities of the home environment, including cognitive stimulation and emotional support. Home characteristics, in turn, predict children's cognitive development and IQ. Ceci (1996) even found that parents' education is a better predictor of children's IQ than is family income (cf. Grissmer, Flanagan, & Williamson, 1998). Not only will the quality of the intellectual experience be richer (in an important sense) for children of university-educated parents, but family life will often be suffused with the valuing of educational achievement, with expectations concerning reasonable and possible educational goals, and with dispositions that support academic tenacity and a work ethic, especially with regard to the complex and symbol-rich tasks that typify formal education and symbolic-analytic work.

JOB EXPERIENCE

It would be a mistake to think that work experience is unrelated to cognitive development. Work actually constitutes a phase of education, not merely a life

stage for which education is preparatory. Of course, jobs—like families and schools—differ in their educative quality. In Reich's (1992) terms, routine production jobs are poor in educative value, but symbolic analyst positions are rich in their potential to expand cognitive capability. This is clear if one considers the educative value of jobs that require only mindless repetition versus those that require a worker to confront and solve new and complex problems on a daily basis. The latter kind of job—that of the symbolic analyst—evokes and exercises the cognitive competencies described by the term *intelligence*. Schooler (1984) showed that jobs demanding initiative, judgment, and independent thought actually increase the intellectual flexibility of workers over time, and encourage a value system that prizes self-direction over conformity.

The best-rewarded and most prestigious jobs have this quality of symbolic analysis. For those who think for a living, work is never business as usual, but rather is defined by the problem du jour. According to Stewart (1997, p. 202), "Instead of jobs, we have projects." To be effective, workers must maintain cognitive flexibility while accessing their own and others' expert knowledge base. Yet the expert's knowledge base is itself shifty, subject to revision and constant expansion. These workers must also be able to interact smoothly with people who carry cognitive repertoires different from their own. In today's workplace, complex projects are commonly posed to groups of people assembled in the hope that their separate cognitive contributions will synergize. The work group takes on a project (i.e., complex problem), solves it, and then disbands so that its members can join yet other ad hoc groups that address other problems.

Job experience may exert intergenerational effects. I have already proposed that university-educated parents will be different *sorts* of parents than those who are not comparably educated. The same might be true of parents who have different job experiences. There are the obvious cognitive advantages associated with high income, and incomes tend to be higher for symbolic-analytic jobs. Family income can affect the experience of the child all along the developmental continuum by contributing to differences in the quality of prenatal experience, preschool experience, schooling, the likelihood of obtaining a college and postgraduate education, and occupational aspirations. More directly, children's social environments, including the values that define the professional class, might be taught at home and reinforced through interaction with other professional-class families, through peer culture, and through the culture of the local school (Harris, 1995). The high valuation of independent thought and self-direction encouraged by parents' intellectually demanding jobs seems likely to be passed on to children, who would then be groomed for their own life careers as symbolic analysts (Schooler, 1984). Such experiences foster in children the tendency, willingness, and ability to engage in problem-finding and problem-solving behavior in complex environments—the bread and butter of their parents by virtue of their membership in the society of the cognitive elite.

EXPERIENCE IN OLD AGE

The trend toward gentrification, especially in affluent and technology saturated nations, is now common knowledge. Gentrification may have economic consequences. We know that as people age, crystallized intelligence tends to grow or at least stabilize, whereas fluid intelligence declines (Stanovich, West, & Harrison, 1995). A case can be made that economic productivity depends increasingly on the exercise of fluid ability because of the constant need to innovate (Hunt, 1995). As life spans stretch, will productivity drop? Not necessarily. The deliberate enhancement of cognitive abilities, especially fluid intelligence, would address Hunt's (1995) concern that the workforce of the future might have insufficient cognitive flexibility to be economically competitive.

The direct training of fluid intelligence has in fact been demonstrated in elderly populations (Willis, Blieszner, & Baltes, 1981). More generally, there is a new optimism that the cognitive system of adults, including older adults, is far more plastic than previously recognized. For example, gains in crystallized intelligence over the life span appear to be largely mediated by exposure to print (Stanovich et al., 1995), an experiential factor that can be controlled by the individual and encouraged by the culture. Evidence is accumulating that certain kinds of experience can lead to reorganization of the adult brain, even late in life (Nelson, 1999). A cognitively interesting and challenging environment, as well as physical exercise, can increase the production of brain molecules known as *neurotrophins*, whose function is to stimulate the growth of neurons and to improve local brain vascularization (Cotman & Neeper, 1996). Neurotrophin levels are higher and cognitive functions are more advanced in physically active men and women than in sedentary peers. The phenomenon of activity-related brain plasticity in the aging population highlights "the fundamental need to maintain and perhaps even increase brain stimulation in aging" (Cotman & Neeper, 1996, p. 293). All such related brain-enhancing and brain-preserving activities can be thought of as broad-sense education.

Equally encouraging is the finding that new brain neurons can be formed in adults, even the elderly. It has long been assumed that the loss of brain cells in adults is irreversible—that new brain cells cannot be developed. The doctrine of the monotonic decline of brain neurons is now known to be false. Newly generated brain neurons have been detected in the hippocampus (a brain structure that plays a crucial role in the formation of long-term memories) in human adults in their 60s and 70s (Eriksson et al., 1998). The investigators who discovered this phenomenon also pointed out that neurogenesis in laboratory animals has been linked to environmental stimulation and to exercise (Hotz, 1999). Connections between specific activities and neurogenesis have not yet been demonstrated in humans, but present a fascinating possibility. The current findings are themselves significant because neurogenesis among older adults suggests that "the human brain retains the potential for self-renewal throughout life" (Eriksson et al., 1998, p. 1315). The maintenance and enhancement of intellectual functioning could yield many benefits, not least of which is a more satisfying life for the elderly.

In the future, "smart drugs" may play a prominent role in maintaining and enhancing cognitive ability in people of all ages, but especially the elderly. There is enormous interest, both theoretical and commercial, in exploring physiological and pharmaceutical pathways that might lead to the enhancement of cognitive performance. The physiology of memory at the level of synapses is leading to the design of pharmaceuticals that enhance memory and, possibly, other cognitive functions. As of 1999, the FDA had approved only two memory-enhancing drugs, Tacrine and Donepezil; both were intended for patients with Alzheimer's disease (Holloway, 1999). These drugs work by inhibiting the breakdown of acetylcholine, a neurotransmitter that appears to be important in memory formation. Some of the drugs now under development target receptors in the hippocampus. These target sites include NMDA receptors and a subclass, AMPA receptors, for which a class of memory-enhancing drugs called *ampakines* is being developed. In early clinical studies, ampakines doubled the recall of elderly subjects (Lynch, 1998). Clearly, as the population gentrifies and life expectancies lengthen, the market for smarts in a bottle will grow.

NUTRIENTS AND TOXINS

Under the very broadest construal of *education*, we might place differences in exposure to nutrients and toxins, and their effects on cognition. Nutrients and toxins are, after all, aspects of the environment that either promote or limit development, and that are controllable. What is not in doubt is that there are important differences among children and adults in their exposure to molecules, "good" and "bad," that are relevant to cognitive performance. Exposure to nutritive and toxic molecules has special importance in the prenatal months, and during childhood. However, because nutrients and toxins have documentable effects all along the life span, this section is organized separately from the previous sections based on life stages.

Nutrition is far more important to the developing mind than is commonly recognized (Eysenck, 1991). Lynn (1990) advanced the idea that worldwide increases in IQ during the past century—the Flynn effect—might be attributed to global improvements in nutrition. To demonstrate that this is plausible, Lynn cited research showing that, in children and animals, suboptimal nutrition is associated with deficiencies in neuronal growth and myelination, and in the formation of synaptic connections. Even if widespread nutritional improvements have supported a general increase in IQ, chronic malnutrition can still be found around the world, including in economically developed countries (Karp, 1993).

Vitamin Supplementation in Britain

There is now a body of research showing that nutritional supplementation in the form of multivitamin tablets can lead to IQ enhancement (Eysenck, 1998). In a double-blind, placebo-controlled study, Benton and Roberts (1988) detected a 9-point rise in nonverbal IQ among British children who received a vitamin supplement over an 8-month period. No such rise was detected in the placebo group. A nutrient analysis of the diet of participants, ages 12 and 13, showed that U.S. RDAs were met for most nutrients prior to the intervention. There was, however, considerable variation around mean nutrient intakes, and for a subset of participants substantial deficiencies were found for vitamin D, folic acid, calcium, iron, and other trace minerals. Benton and Roberts (1988) interpreted their data as showing that gains in nonverbal IQ represent increases in the "more biological" fluid intelligence as a consequence of improved neural functioning. A lack of improvement in nonverbal IQ was interpreted to mean that crystallized intelligence, which is more clearly identified with accumulated experience, would not be expected to rise in a study of such short duration.

Vitamin Supplementation in California

Similar effects were reported by Schoenthaler, Amos, Eysenck, Peritz, and Yudkin (1991) from research conducted among eighth- and tenth-grade California schoolchildren. In a controlled study that varied the level of vitamin supplementation to 50%, 100%, and 200% of RDA, IQ gains associated with supplementation were again more pronounced on tests of nonverbal fluid intelligence than on crystallized intelligence. After only 4 weeks, the 200% RDA supplementation group experienced a significant gain in fluid intelligence as assessed through Raven's Matrices. In the longer term (13 weeks), gains in nonverbal IQ (WISC-R) were larger in the treatment groups than in controls, but the effects were statistically significant only for the 100% RDA group, which demonstrated a gain over controls of 4.4 IQ points. The 100% RDA group also outperformed controls on the reading comprehension and mathematics comprehension subtests of the CTBS achievement battery.

Nutrient deficiencies need not be severe to have cognitive effects; subclinical deficiencies in vitamins and minerals can result in decremented cognitive performance before signs of physical deficiency are observed (Yudkin, 1991). In the theoretical framework employed by Schoenthaler and colleagues (1991), only those students whose diet was nutritionally suboptimal could be expected to benefit significantly from vitamin supplementation. Accordingly, the researchers distinguished between "responders" (those gaining 15 or more IQ points) and "non-responders" (all others). Preliminary analyses of blood samples taken before and after the intervention showed that "responders" were more likely to have lower concentrations of nutrients prior to the intervention, and were also more likely to

experience significant changes in blood nutrient levels as a result of supplementation. More detailed blood analyses were reported later (Eysenck & Schoenthaler, 1997). The re-analyses included only those students who initially had low blood concentrations of vitamins. Within this subset of students, the 100% RDA group gained 8.1 IQ points over the placebo control group, and the 200% RDA group gained 5.1 IQ points relative to controls. IQ gains in the 100% RDA and 200% RDA groups were both significantly different from the control group, but not from each other. The recognition that some recipients of vitamin supplements responded dramatically and others did not suggests that vitamin supplementation might have special importance for young learners growing up in conditions of poverty or disadvantage, and in developing countries (Eysenck, 1991).

Dietary Changes in New York City

Improvements to the nutritional quality of diets have been shown to impact school achievement directly (Schoenthaler, Doraz, & Wakefield, 1986). In a study involving approximately one million school children in public schools of New York City, dietary improvements to school-served breakfasts and lunches were phased in over a 3-year period. Those improvements involved the reduction of sucrose, synthetic food colors, and preservatives. In Figure 8.2, diagonally hatched bars display the effects of those dietary improvements on school achievement tests, expressed as national rankings.

The phased-in dietary changes were organized as follows: The first change, implemented in 1979-80, involved the reduction of sucrose levels; the second change, implemented the following year, entailed the elimination of selected food colors. Both changes were associated with rises in percentile rankings. No additional dietary changes were made in the 1981-82 school year, and the percentile rankings remained unchanged. The third dietary change, made during the 1982-83 year, was the elimination of the preservatives BHT and BHA. That change was associated with a further improvement in academic achievement scores. During the 4-year implementation period, the New York City public schools improved their academic performance, expressed as national percentile rankings, from 39.2% to 54.9%—a 15.7% gain.

Subtler effects contribute to the richness of findings and the implications of this study. For example, academic gains were strongest in those schools having the highest percentages of students receiving school meals. Dietary improvements had three times the effect in schools having the most participation in school meals compared to those having the least. Perturbations in national rankings during the 3 control years prior to the study might also be linked to dietary changes. In particular, the 1977-78 school years shows a slight, but statistically significant, improvement in performance compared to the year before. The authors noted that during the 1977-78 "control" school year, the amount of fat in school meals was reduced.

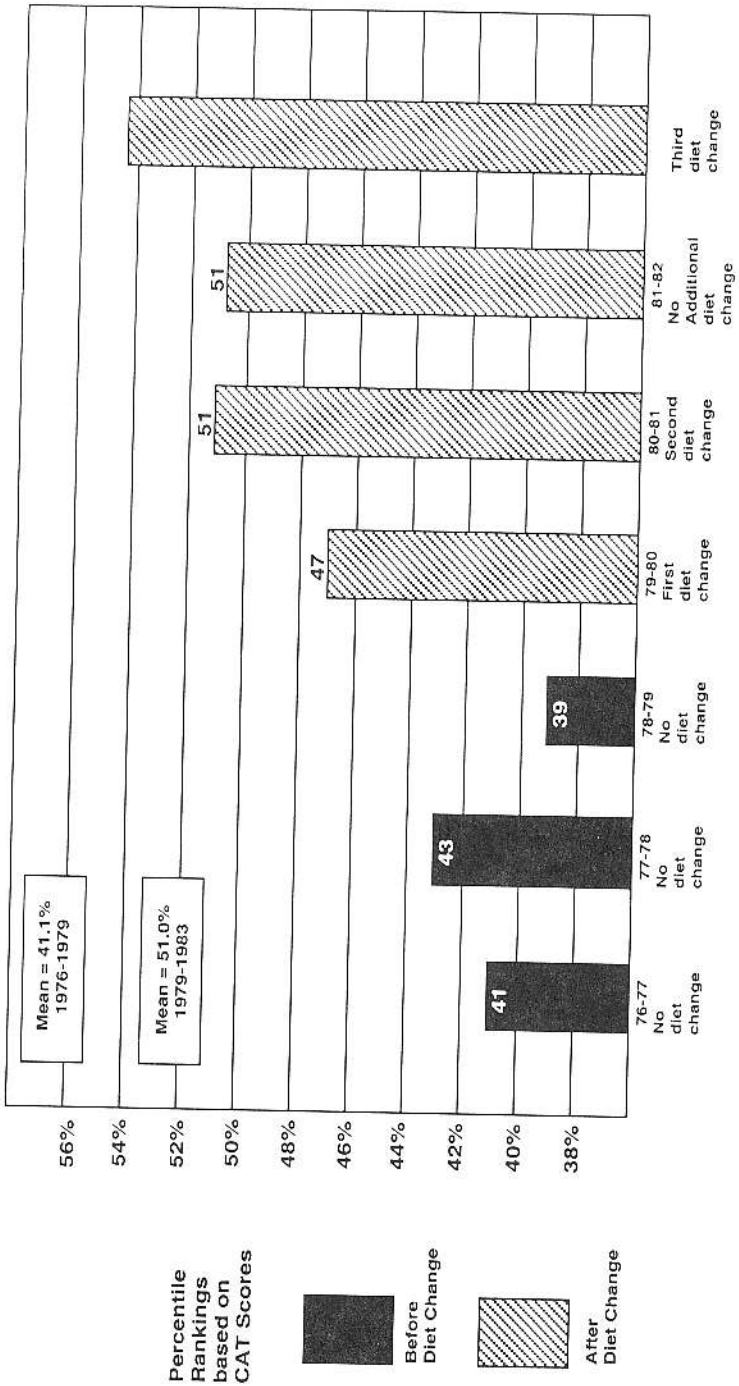


FIG. 8.2. National rankings of 803 New York City public schools before and after dietary changes. The achievement measure, CAT, refers to the California Achievement Test. From "The Impact of a Low Food Additive and Sucrose Diet on Academic Performance in 803 New York City Public Schools," by S. J. Schoenthaler, W. E. Doraz, and J. A. Wakefield, 1986, *International Journal of Biosocial Research, 8*(2), p. 189. Reprinted with Permission.

In interpreting these gains, the authors expressed doubt that academic benefits resulted directly from the elimination of idiopathic effects, such as specific food allergies. A more likely explanation is that the reduction or elimination of sucrose, food colorings, and preservatives resulted in a general improvement in the ratio of nutrients to calories. The dietary reduction of nutritionally poor (e.g., highly processed or empty calorie) foods presumably led to a caloric gap, which students filled by increasing their intake of nutritionally superior foods. This study shows that nutrition is germane to learning outcomes in the United States. Chronic malnutrition is not a phenomenon restricted to Third World countries; American children living in conditions of poverty commonly suffer nutritional deficiencies (Karp, 1993). More generally, nutritionally poor diets are concomitant with poverty and almost certainly contribute to differences in cognitive outcomes among racial-ethnic groups (Sewell, Price, & Karp, 1993).

Protein Supplementation in Guatemala

In developing countries, chronic dietary protein deficiency has long been known to be a major health problem affecting millions of children. The clinical manifestation of protein deficiency is the syndrome known as *kwashiorkor*, identified by hair and skin dyspigmentation, liver hypertrophy, and behavior marked by apathy and listlessness. Protein supplementation can be effective in improving the cognitive performance of children at risk for clinical protein deficiency. In one study conducted in four Guatemalan villages, children in the treatment group were administered a liquid protein supplement twice daily, beginning as early as infancy and extending up to age 7 (Pollitt et al., 1993). For a subset of participants, supplementation was available prenatally through the participation of their mothers.

In comparison to placebo-administered controls, the experimental subjects scored significantly higher in school-related achievement tests, on cognitive reaction time tasks, on IQ as measured by Raven's Progressive Matrices, and on a general cognitive factor. However, the interactions among predictors reveals the true multideterminate nature of cognitive outcomes. In particular, treatment effects were most pronounced in subjects who came from the poorest families. In the treatment group, protein supplementation effectively neutralized the association between family wealth and cognitive outcomes, and so acted as a "social equalizer" (Pollitt et al., 1993, p. 79). Supplementation also interacted with educational experience as measured by maximum grade attained. This latter interaction suggested a synergistic effect of adequate nutrition and educational opportunity such that nutritional factors increase in importance with greater exposure to schooling (Pollitt et al., 1993; Wachs, 1993). Long-term effects were observed in a cross-sectional follow-up study 11 years after supplementation was halted, when subjects were adolescents and young adults. Main effects for protein supplementation were again found on measures of fluid intelligence (i.e., Raven's Matrices), on literacy, and on numeracy. As before, these effects were most pronounced among participants from poorer families.

It is too simple to think that the causal chain linking dietary improvements with cognitive benefits operates exclusively through establishing a more adequate neural substrate for learning. Nutrition probably does have direct effects on the CNS, but an improved diet can also lead to different qualities of behavior in the child and in the caregiver (Ricciuti, 1993; Wachs, 1993). In a supplementation study in Mexico, Chávez and Martínez (1975) found that improved nutrition had large effects on the quality of parent and child behavior. Children who were nutritionally "supplemented," starting at 6 weeks gestation, displayed much more independence, exploratory behavior, and complex play than did "nonsupplemented" control children. Parents of nutritionally "supplemented" children, in turn, were much more responsive: Mother-child speech interaction was twice as frequent, and father-child play was much more common in supplemented children than in controls. Thus, the diet-cognition link may be moderated by the quality of the child's experience, which in turn is affected by the child's own initiative.

Toxins

Along with nutritive molecules, the cognitive effects of environmental toxins must also be considered. High-dose lead exposure, for example, has long been associated with decrements to cognitive and motor performance (Harris, Clark, & Karp, 1993). Low to moderate lead exposure has been found to impair gross and fine motor control in children (Dietrich, Berger, & Succop, 1993). The association between low-dose lead exposure and cognitive decrement has been less clear. Studies of the cognitive effects of lead have sometimes yielded contradictory findings, but pertinent studies have been uneven in data and design quality. Needleman and Gatsonis (1990) conducted a meta-analysis of the effects of lead exposure on IQ, using only studies that had adequate measures of exposure and cognitive outcomes, and measures permitting covariate control over possible nonlead confounds. In 11 of 12 studies, they found a negative effect of low-dose lead exposure on IQ (joint $p < .0001$). Blood serum lead levels between 25 and 40 picograms per deciliter were associated with a 5-point IQ disadvantage, which translates to a magnified incidence of mild mental retardation. On the basis of their analysis, the investigators concluded that "the hypothesis that lead impairs children's IQ at low dose is strongly supported" (p. 673).

Even maternal exposure can have effects on children: Lead is now known to cross the placenta (Dietrich, Berger, & Succop, 1993), and there is a "clear relationship between umbilical cord lead levels and later development at 6 to 24 months" (Needleman & Gatsonis, 1990, p. 677). Maternal lead levels above 10 micrograms per deciliter are known to suppress the cognitive development of children (Harris et al., 1993). Although lead abatement programs have been in place for some time, large numbers of children still suffer from low-level lead exposure, especially from lead-based paint in dilapidated and substandard housing. Even low-level exposure is serious because there is unlikely to be a "safe" threshold below which negative effects can be ruled out. Moreover, it is not clear that chelation therapies are effective; they may, in fact, exacerbate the problem (Harris et al., 1993).

Another class of toxins, insecticides, are a major cause for concern because, as neurotoxicants, they are "deliberately designed to sabotage biological mechanisms," and their widespread use over decades has led to their "total global distribution in human tissues," and indeed the entire biosphere (Weiss, 1997, p. 255). Most research has focused on the potential carcinogenic effects of pesticides, but few studies have examined their possible role as agents of developmental disabilities. Acute poisoning by organophosphorus compounds, such as malathione, has been found to have long-term neurotoxic consequences in adults, including diminished IQ (Weiss, 1997).[6] Organochlorine compounds, which include DDT, are potentially much more dangerous because they biodegrade slowly and accumulate in fat tissues. Organochlorines can also cross the placenta and are passed on through breast milk. As with organophosphates, acute exposure to organochlorines is associated with diminished cognitive functioning in adults and lower IQ in children. Effects of chronic, lower-level exposure (e.g., through residues on food) are less certain. However, even acute pesticide poisonings are common, affecting at least 45,000 people each year in the United States alone.

CONCLUSION

This main theme of this chapter is that a broad range of experiential factors have demonstrable effects on cognitive development, including IQ. Although the experiences of infancy and childhood have special importance in shaping cognitive growth, the experience stream all along the life span—from prenatal life to old age—can boost, nudge, and bend the pattern and pace of cognitive growth or decline. These experiences include, but are not limited to, formal education. Cognitive growth is multidetermined by experiences that vary in educative quality. In light of this, it makes sense to redefine the word *education* to embrace all experiences that enhance the readiness of people to be effective in a complex, problem-centered, and symbol-rich society. Even as IQ scores are rising around the world, we now understand enough about the kinds of experience that enhance intelligence that, collectively, we can cultivate richer cognitive outcomes for everyone.

NOTES

1. Strangely, quality of experience can exercise effects even well *before* conception. In one study, for example, incidences of anencephaly and spina bifida were found to be inversely related to the social class of the child's *maternal grandfather* (Joffe, 1982). That is, these birth defects were more frethe body over time and can cross the placenta (Dietrich et al., 1993).

2. According to the "good enough" parenting hypothesis, parents have little differential impact on children's cognitive development; rather, within a range of "species-normal" home environments, children will seek certain kinds of experience, and this experience-seeking behavior is strongly guided by the child's own genotype (Scarr, 1992). However, the meaning of "species-normal" environments, although perhaps straightforward in nonhuman species, is complicated by the huge variability among human cultures in the existence and relative valuation of symbolic inventions (Gardner, 1983). For example, whether a culture (or a family within a culture) is literate or nonliterate will permit or preclude literacy among children, and this division will cascade to all manner of cognitive outcomes (e.g., crystallized intelligence). Formal education (schooling) is another example of an invention of culture that complicates the meaning of "species-normal." Other inventions, such as computational and information technologies, may ultimately have similar effects on human experience and on the shape of growing minds. Studies of genetic influences on cognitive development within relatively homogenous populations are unlikely to register the effects of large variations in environments that are all "species-normal," perhaps leading to the unwarranted conclusion that these variations do not matter much to the developing child.

3. Other research corroborates the effect: Performance on Raven's Matrices, a test of fluid intelligence, is sensitive to secondary education (Greenfield, 1998).

4. Gordon observed similar patterns in his study of gypsy (Roma) children (Freeman, 1934).

5. Compare with effects observed among English canal boat children (Gordon, 1970/1923), described earlier.

6. On August 2, 1999, the U.S. Environmental Protectional Agency imposed limitations on the use of certain organophoshates (e.g., banning the use of methyl parathion on fruits), recognizing for the first time their potential to disrupt the neurological development of children (Shogren, 1999).

10

Cultivating Intelligence

In lamenting the misguided antipathy between proponents of traditional education and advocates of progressive education, Dewey (1938) held out the possibility that, in certain cases, neither approach was educative. In making this claim, Dewey was asserting that the word *education* carries independent standards that experiences in schools may or may not meet. To Dewey, the important question was not whether progressive or traditional education was to be preferred, "but a question of what anything whatever must be to be worthy of the name education" (p. 91).

As we approach the idea of education as a way to cultivate intelligence, it becomes necessary to decouple the terms *education* and *schooling*. In common parlance they are used synonymously, as if schooling "constitutes *the* educational system" (Brandwein, 1981, p. 9), but philosophers of education from Plato to Dewey have recognized the difference. Brandwein (1981) divided the two terms, explaining that:

> Schooling attempts to transmit the concepts, values, and skills prized by a community acting under constraints of public custom, rule, and law (local, state, and federal). Education, on the other hand, affects all of life and living and comprises all influences, in school and out, that affect and effect changes in the individual—whether of habituation, of character, or of intellect. These changes in behavior occur throughout life. (p. 9)

The meaning of the Latin root *educere* is "to draw out." Education can be construed as any process that extends a human being in directions that build capacity and that lead to yet further growth, wherever and however that occurs. Educative experiences build competencies that are, in Snow's (1991) terminology, *propaedeutic*, or "needed as preparation for . . . [some future] success" (p. 257). A broad definition of education does not specify curriculum or venue.

Dewey's question as to what constitutes education is provocative on two counts. First, it implies that the institution of schooling is not equivalent to education. The school, as the primary site of institutional education, can in fact be miseducative, failing its mission as an educative agent, and perhaps even reinforcing inequities in the larger society (Shujaa, 1993). Cognitive differences among people are also traceable to experiences that precede and parallel schooling; through those experiences, cognitive abilities are stimulated or stunted all along the life span. The second implication of Dewey's question is that experiences can be evaluated as to their educative value. Dewey offered some guidance on this point.

In particular, he suggested that the most important quality of experience is its *continuity*, which is the ability of experience "to live fruitfully and creatively in subsequent experiences" (1938, p. 28). If intelligence consists of cognitive and noncognitive functions that lead to effectiveness across a wide situational spectrum, then experiences that cultivate intelligence satisfy the principle of continuity.

How can intelligence be cultivated? The chapters on experiential factors associated with IQ and on specific interventions that led to IQ gains are replete, conceptually and strategically, with ideas on how future interventions might be organized. Existing theories of intelligence, perhaps including the model that I have advanced, can help structure efforts to enhance intelligence more programmatically and deliberately. In this chapter, I have distilled some of the research literature on intelligence-promoting experiences to propose ten strategies that can organize efforts to enhance intelligence.

TEN STRATEGIES FOR CULTIVATING INTELLIGENCE

The School

1. Establish an Intelligence-Enhancing Curriculum for Every School. If the goal of raising intelligence were recognized by society as achievable and important, schools would have a vital role to play. When human intelligence is reinterpreted to be teachable and learnable, formal education can take on new meaning. In particular, it becomes conceivable that the direct enhancement of intelligence could be adopted as an explicit or even primary goal of schools. If the deliberate cultivation of intelligence were embraced as a central goal of formal education, the very meaning of education would by that fact be transformed. Intelligence would no longer be seen as only an input or raw material for education, but also, and more importantly, as a product.

Historically, educational systems have not adopted the teaching and learning of intelligence as an explicit goal, nor have educational systems been conceptually equipped with the necessary models of cognitive functions underlying intelligence. Instead, those functions have been learned incidentally and incorporated into the intelligence repertoire as *tacit* knowledge. A. D. deGroot (1948) observed that intelligence consists largely of "methods of thinking, . . . of searching and finding new solutions to problems" (p. 315). The intelligent person "adopts them, largely unconsciously, from others" (p. 316). At the level of the individual learner, the acquisition of the intelligence repertoire has amounted to a kind of code breaking, a quiet extraction of cognitive functions that are encrypted in the surrounding culture. But there is no reason why knowledge acquired incidentally through passive enculturation must remain tacit. Intelligence should be taught directly.

Cognitive theory now supplies an account of the cognitive functions composing intelligence. An appreciation of the functions most characteristic of intelligence

makes them candidates for the organizing elements of the curriculum, or what Perkins (1992) called the *metacurriculum*. Some curricula have been explicitly organized around the goal of developing intelligence or intelligences. Gardner's (1983) theory of multiple intelligences, for example, has inspired the mission and curriculum of the Key School in Indianapolis (Gardner, 1993b; Gardner & Hatch, 1989), and has been used by thousands of teachers in diversifying symbol modalities and modes by which learners express proficiency. Many other curricula that aim to develop cognitive strategies, thinking skills, critical thinking, and the like probably also serve to develop the repertoire of intellectual functions that are general and powerful enough to be called *intelligence* (Nickerson, Perkins, & Smith, 1985; Paul, 1993; Perkins, Goodrich, Tishman, & Owen, 1994; Pressley & Harris, 1990; Whimbey & Lochhead, 1991).

The typical school curriculum already develops intelligence to some degree. Mathematics is a good example. Clearly, much or most of high school and college mathematics exceeds the numeracy needed by citizens in their daily lives or on the job. The study of advanced algebra, trigonometry, and calculus might now perform the function once ascribed to Latin.[1] Although not justified in these terms, the mathematics studied by academically oriented high school students probably serves to "exercise" the mind's capacity to think abstractly, to apprehend complexity, and to solve problems through the manipulation of symbols—just the sorts of cognitions that conform to information-processing characterizations of intelligence and to the work of the symbolic analyst. As Cattell (1987) observed, it is "no accident" that schools "concentrate on intelligence-demanding subjects" (p. 147).

The cultivation of intelligence can become much more focused by targeting the associated intellective functions either independent of specific content or in conjunction with subject matter. Although much is made over whether thinking-based curricula ought to be content independent or embedded in school subjects, the important thing is that it be done. If the regular curriculum incorporated the teaching of intelligent cognitive functions directly, those functions could be built into the design of curricula as cross-cutting cognitive objectives. In assessment, the measurement of cognitive outcomes could take advantage of a long tradition of designing test specifications to include both content and process dimensions. If subscores were reported along content and process dimensions, test results could directly contribute to the goal of teaching intelligence. All these changes would involve shifting curriculum and assessment to support not only academic achievement in subject areas, but also the development of cognitive abilities (Kvashchev, 1980).

Theories of cognitive development and the history of cognitive interventions show that the quality of early childhood experience is crucial. Many investigators have stressed the importance of developing cognitive abilities in preschools (Barnett, 1995, cited in Jencks & Phillips, 1998a; Ceci & Williams, 1998; Kornhaber, 1998). The proposal to emphasize cognition in preschool is

controversial, but given the social consequences of differing experiences before a child first sets foot in a classroom, the potential benefits of a cognitively oriented program are compelling, especially for children who are at risk for failure in school. Successful preschool programs have, in general, created an environment of high complexity, to which children were expected to respond (Detterman, 1982). The quality of interactions between children and preschool staff is crucial: Children's language comprehension abilities have been found, for example, to be related to caregivers' mean sentence length and use of complex sentence structures (Tizard, Cooperman, Joseph, & Tizard, 1972).

Teaching for intelligence means engaging in an entirely new enterprise; it calls for a redefinition of what constitutes an educated person and what constitutes an educative experience. Should this goal be adopted, the meanings of both *education* and *intelligence* must both expand. That is because the universe of cognitive competencies composing intelligence is not yet fully known, nor are the kinds and qualities of educative experiences that engender them completely understood. Thus the questions: "What is intelligence?" and "What is education?" must remain open.

2. Recognize the Convergence of Racial/Ethnic Cognitive Distributions as Achievable and Desirable. For decades, a span of one standard deviation has separated the IQ distributions of Black and White Americans, and has persisted with such tenacity that it had seemed to be a permanent fixture. However, recent data on cognitive differences between Black and White students as manifest in IQ scores and academic achievement have shown that the cognitive gap is not permanent—and that it has in fact shrunk since 1970. This documentable narrowing of the gap makes an environmental explanation of Black-White cognitive differences more plausible now than ever (Jencks & Phillips, 1998a; Kaus, 1995).

The inferences are hopeful: The fact that the gap *has* narrowed means that it *can* narrow, and because the gap *can* narrow it is conceivable that it can close completely. On this point, even the hereditarians Herrnstein and Murray (1994, p. 293) made a startling concession, granting that "there is no reason why [the gap] shouldn't" continue to converge, with parity reached "sometime in the middle of the twenty-first century" (p. 293). However, their optimism was short-lived. Before they completed that sentence, they cast aside the monumental implications of what they had just written with the half-hearted hedge that "linear implications over such long periods are not worth much"!

Those particular linear implications are worth quite a lot—although Herrnstein and Murray (1994) were actually making a technical point, referring to the limited dependability of trend extrapolations. Nonetheless, a shrinking cognitive gap bodes well for the cause of equity. Reducing differences in cognitive ability and achievement, for example, is likely to influence racial disparities in educational attainment. High-scoring Black students are actually *more* likely to complete college than are White students with comparable test scores (Jencks & Phillips, 1998a). Jencks and Phillips (1998b) asserted that between-race differences in cognitive abilities can explain the entire Black-White gap in college graduation, and most of the discrepancy in earnings. The implication here is that Black and White populations are not so different on noncognitive influences on achievement, such as aspirations for success. The fact that the gap between Black and White students is narrowing on measures of cognitive achievement and ability, and that the abilities tapped by tests appear to be instructionally tractable, "could be very good news" (Jencks & Phillips, 1998b, p. 71).

3. Cultivate Fluid Intelligence Through Problem Solving. Problem solving and problem finding can serve as a general model for intelligent thought and action. Models of problem solving in novel situations, in particular, strongly resemble models of fluid intelligence. When the family resemblance between problem solving and fluid intelligence is recognized, this knowledge can be used to design intelligence-enhancing experiences. Tradition, however, may present a hurdle. In schools, crystallized intelligence tends to be emphasized at the expense of fluid intelligence (Lohman, 1993). Snow (1982a) showed that highly structured direct teaching can produce large gains in crystallized intelligence, but in some cases these gains are accompanied by declines in fluid intelligence with respect to control groups. Correcting the crystallized/fluid imbalance can be tricky because it depends on posing problems that are sufficiently novel such that students cannot rely on already learned procedures, yet not so novel that the students flounder. Balancing novelty and familiarity requires a delicate calibration of environmental demands to a student's zone of proximal development (Vygotsky, 1986/1934) along the novelty-familiarity continuum (Sternberg, 1985a). What complicates the matter is that this calibration point not only varies from student to student, but is itself a moving target because it can change rapidly with experience (Lohman, 1993). The ability to identify and hit that target consistently is a skill belonging to the very expert teacher.

If problem solving is to be used as a general model against which educative activities are compared, it is important that the nature and scope of problems typical to academic settings be reconsidered. Fig. 10.1 displays two dimensions of the space in which problem solving takes place. On the horizontal axis is the timeline over which problems are posed and solved. This timeline ranges from a single second to a life span. The vertical axis describes the complexity and teleological reach of the problem, and this dimension stretches from simple perception to the construction of values and meaning. Between the two axes is the problem space in which intelligence is exercised, and this space is divided by an arc that separates the "academic culture problem space" from the "life problem space." This division signifies that intelligence tests and school curricula have been mostly concerned with the lower-left corner of the problem space, whereas intelligent thought and action that make for successful lives stretch up and to the right. The diagram implies a need to revise education systems not only to emphasize

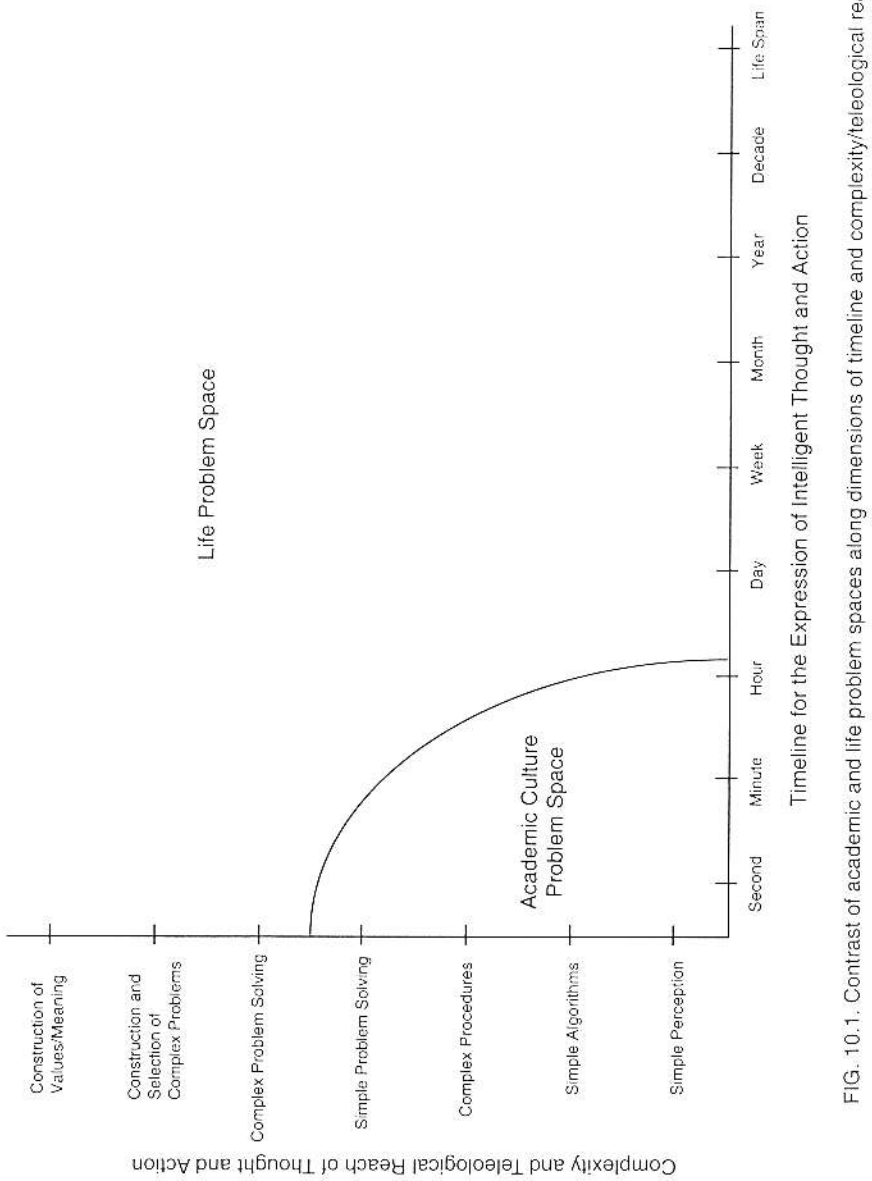


FIG. 10.1. Contrast of academic and life problem spaces along dimensions of timeline and complexity/teleological reach.

problem solving as the essence of intelligence, but also to more fairly represent the range of problems on which intelligence operates.

Besides recognizing that the full problem space of intelligence is far larger than the reach of most academic tests and tasks, it may be important to consider "noncognitive" aspects of broad-sense intelligence. Broadening the criteria for recognizing intelligent thought and action might mean expanding the range of psychological functions constituting intelligence to include conational (i.e., motivational and volitional) and emotional aspects (Hilgard, 1980; Snow, 1980b; Snow, Corno, & Jackson, 1996). This is because movement within a problem space is impelled and sustained by all manner of "hot" needs and rewards, not just coolly stated rational objectives.

4. Cultivate Crystallized Intelligence Through Deep Literacy and the Pursuit of Schema Quality. The strong connection between crystallized intelligence and proficiency with language, especially text comprehension, reinforces the primacy of literacy as an organizing goal of formal education. Although the promotion of crystallized intelligence can be accomplished through many forms of experience, the medium of text is especially potent. The amount of reading engaged in by students is associated with school achievement across race, gender, and SES (Heyns, 1978). Gains in crystallized intelligence over a lifetime appear to be strongly associated with exposure to print; that is, to reading habits (Stanovich, West, & Harrison, 1995). Crystallized intelligence can be cultivated more widely as a greater proportion of the population learns not just the skill of reading, but also the love of it. Developing that love poses a challenge. People who are able to read vary considerably in the extent to which they actually do read. The problem is not so much illiteracy, but *aliteracy*—the ability to read but an unwillingness to do so. There is evidence of a steady decline in reading engagement from the mid-1970s to the present, and a decline in newspaper reading beginning in the early 1900s (Glenn, 1994).

A study of the experiential histories of low-achieving college students illuminated the origins of text avoidance. Duchein and Mealey (1993) found that, as children, many students had been read to by their parents, and that in many cases their primary school teachers had read aloud to them. These experiences were remembered with considerable pleasure. Unfortunately, the frequency of being read to tapered off dramatically in the later grades and in high school. Competing activities and diversions, including television, led many students to reject any book reading that was not required as coursework. Many participating college students had not read for pleasure in years, and some felt aversion or dread about the prospect of reading a novel. The pleasure of text, however, can be recovered. When assigned to read the novel *The Prince of Tides* (Conroy, 1986), many students were surprised to discover that they actually enjoyed it. Some even began to read other books for pleasure.

Although text can serve as a strong medium for growing crystallized intelligence, the mechanism by which intelligence is crystallized is through the

development of schemas. Learning, understanding, and critical thinking can all be gathered under the umbrella of improving schema quality. Likewise, the primary function of metacognitive thought can be seen as the improvement of schema quality. In my model, I have cast the pursuit of schema quality as depending on standards against which existing schemas can be judged. This comparative function is described in somewhat different terms in Perkins' (Perkins, Jay, & Tishman, 1993) theory of thinking dispositions, Paul's (1993) identification of intellectual virtues, and Baron's (1985) proposal that the central activity of rational intelligence is cognitive search. To the degree that such standards as clarity, efficiency, and integrity can be internalized and deployed as self-test procedures that are habitual, crystallized intelligence will grow.

Teachers can do a lot to promote the kind of intellectual search that promotes schema quality. Doing so depends partly on establishing a suitable classroom environment. Building a tolerance for uncertainty and ambiguity is important contextually, but this is likely to make the classroom environments less structured and less predictable, a potential worry if the social control of students is an issue (Nickerson, 1986a). In this vein, the curricular overemphasis on crystallized knowledge, often without understanding, may largely function to establish and maintain a "safe" social order because, for the teacher at least, the conceptual ground to be covered is familiar and predictable. Tidy conceptual structures can reinforce neat and predicable social structures. Students may wish to cooperate with this arrangement because by it they suffer less discomfort of effort, complying with an unspoken contract that Gardner (1991, p. 141) called "correct-answer compromises." When such a compact is reached, real understanding is unlikely to be attained (Gardner, 1991; Schank, 1986), and the development of fluid abilities is completely thwarted.

5. Abandon the False and Destructive Antithesis of Higher-Order and Lower-Order Cognitive Skills. The perpetual war between proponents of basic skills and champions of higher-order thinking can lead an observer to believe that educational reform can never be more than the oscillation of a pendulum. The problem lies in the misunderstanding that lower-order and higher-order processes are antagonistic. In reality, they are complementary. Higher-order processes depend on the skillful exercise (and sometimes, automatization) of lower-order abilities, but the teaching of lower-order abilities is, as an end in itself, an impoverished sort of educational objective. Moreover, it is false to think that lower-order abilities must be developed before higher processes. Their development can and should proceed in parallel.

There is some evidence that skill automatization predicts academic success (Whang, 1991, cited in Jensen, 1992b). Automated skills have value because they free up working memory for the operation of higher-order strategic planning and monitoring, and for creative work. Because the acquisition of automaticity is time intensive, it should target only those processes and knowledge structures that have wide importance. Decoding text is probably the best example of this

kind of skill, because if decoding is laborious the cognitive system will have very little capacity left over for comprehension. At their best, reading and other forms of complex cognition combine automated knowledge with more open-ended search in which automated abilities liberate sufficient working memory for proficient, even expert, performance. When viewed in this light, higher-order cognitive activities are not antagonists of "basic skills"—as if there were a forced choice between them—rather, the most creative and proficient thinking always involves a concert of both higher-order and lower-order abilities.

Sternberg's (1985a) experiential subtheory of intelligence is relevant here. The subtheory holds that intelligence is most clearly demonstrated at the endpoints of a continuum of novelty and familiarity. On the familiarity end, intelligence is manifest in the process of skill automatization. At the novelty end, fluid intelligence is exercised. One might speculate that schools give too little attention to the two ends of the experiential continuum. The flow of experience in schools seems rather to bisect the continuum, requiring neither much adaptive problem solving nor many activities that lead to automaticity or "mastery." If this is an accurate appraisal, and if raising intelligence is adopted as a goal, then more attention should be channeled toward the poles of the experiential continuum.

The Home

6. Recognize the Home as at Least Equal to Schools in Educative Importance. Because intelligence is developed through a broad spectrum of life experience, schools cannot possibly compensate for variation in the experiences that precede, parallel, and follow the school experience. Differences in the intellectual quality of home life are large and relate strongly, although not exclusively, to the nature of parent-child interactions. According to some observers, changing the way parents relate to their children is the "single most important thing we can do to improve children's cognitive skills" (Jencks & Phillips, 1998a, p. 53).

Although reflective thinking is not taught systematically in the home, families differ in the quality of their dinner-table conversations, and in the expectations placed on children for clear thinking (Perkins, 1995). Intelligent habits of mind—ways of thinking about the world, including the kind of questions worth asking and problems worth solving—have a quiet but potent presence in social contexts, including home life. In the long run, the intellectual ambiance of the home carries enormous power and can impede or encourage creative accomplishment. Outstanding contributors to science and culture have typically been raised in homes that were intellectually stimulating and imbued with values encouraging independence, personal expression, and a strong work ethic (Mumford & Gustafson, 1988).

One way to foster intelligence in families is to equip parents with strategies that can advance children's cognitive development. Indeed, parenting "skills" of this sort are a recognized aspect of many cognitive interventions (Ramey & Ramey,

1992). Children's questions, for example, can be addressed at different levels. Parents can ignore or reject a question, furnish an answer outright, or help the child form and test hypothetical answers to the question (Sternberg, 1994a). Parents can learn to adopt "distancing" strategies in their social interactions with children, such that questions and prompts can help children transcend the limitations of the here and now, and extend their cognitive reach to ideas, associations, and relations that are more complex and abstract (Sigel, Stinson, & Kim, 1993). Distancing strategies, initially experienced in the social space of family interactions, can eventually be internalized so that the child can independently discern cause and effect, generate plans, and anticipate consequences. One might think of experiences of this sort as constituting a college-preparatory childhood.

Ramey and Ramey (1992) identified six qualities of experience that should characterize the daily lives of young children: Encouragement to explore; mentoring by adults in basic cognitive skills, such as comparing and labeling; celebration of developmental advances; practice and extension of new skills; protection from discouraging negative experiences, such as unnecessary disapproval; and a rich linguistic environment. These qualities of experience were distilled from dozens of research studies and interventions spanning decades. If applied in the home and elsewhere, they can help ensure that children, even those at risk for failure, will be prepared for success, academic and otherwise.

7. Restrict Cognitively Poor Default Activities. Anti-educational aspects of home life also must be considered. Here I refer to those activities that have a tendency to absorb large amounts of time with little cognitive payoff. Television is an obvious example. It is well known that American children, on average, spend huge amounts of time watching television. In 1988, about one quarter of all fourth-grade children watched television for 6 or more hours each day—and half of all of Black fourth graders watched this much television (Martinez & Lahart, 1990). Television is not categorically bad—viewing may have cognitive benefits up to about 10 hours per week (Williams, Haertel, Haertel, & Walberg, 1982). Beyond a certain point, however, television has a negative effect on school achievement—especially among high-IQ children—possibly because it squeezes out more intellectually rich and demanding activities, such as reading and interaction with adults (Huston & Wright, 1998). Extensive viewing has small but reliable negative effects on reading proficiency, and these effects tend to be more serious in older children (Huston & Wright, 1998). There is some evidence, in fact, that average vocabulary levels (adjusted for education level) declined steadily during the 20th century; during the same period, reading engagement also declined whereas television viewing increased (Glenn, 1994).[2] These data corroborate anecdotal reports. In a study of television's effects, one subject admitted, "After awhile, I lost interest in reading. I got hooked on television and couldn't get off of it" (Duchein & Mealey, 1993, p. 22).

There is also evidence that reducing time spent on viewing television can have a positive effect on children's IQ and cognitive style (reflectivity/impulsivity). Gadberry (1980) matched 6-year-olds on age, gender, IQ, and TV viewing habits, and randomly assigned them to restricted or unrestricted viewing conditions. In the restricted condition, parents limited their children's TV viewing time to half of what it was at baseline levels. The intervention lasted 6 weeks, during which TV viewing averaged 350 minutes per week in the restricted group, and 706 minutes per week in the unrestricted group. During this period, children in the restricted group voluntarily increased the time they spent reading books, a shift that supports the hypothesis that TV displaces other cognitively beneficial activities. Pre- and posttests on the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) revealed a larger performance IQ gain for children in the restricted condition as compared to controls, especially among males. Posttest comparisons on the Matching Familiar Figures Test showed that the two groups also differed in cognitive style, with the TV-restricted group displaying greater reflectivity, and the TV-unrestricted group showing greater impulsivity.

It is possible that television viewing encourages a mental state of passive, uncritical information processing. Research by Salomon (1983) showed that children perceive television to be less demanding than text. Even when information-rich TV programs are presented, children tend to expend little effort to process these programs critically. This may be partly the nature of the medium: Television limits the opportunity to control the allocation of time and effort to reflection by virtue of its programmed pacing of information (Gadberry, 1980); reading, by contrast, engages self-regulation in how time and effort are allocated. Slowing down, skipping ahead, and re-reading are all possible.

The discussion of television raises the larger issue of the impact of mass media and electronic entertainment on cognition. From one point of view, there is a curious contradiction between rising IQ levels and a shift of underlying values toward ever-greater commitment to the intellectually shallow entertainment culture. The culture of the mass media may simply be an expression of abiding cultural commitments. America has always been unfriendly to intellectualism as a form of elitism (and therefore an expression of European values). Nonetheless, some commentators see a decline (Gabler, 1998). Erstwhile "serious" news media are increasingly acceding to the entertainment culture, as depth of analysis gives way to the life dramas of celebrities in the hope of trapping the attention, if only for a moment, of an ever-more-distractible audience. Nowadays, there is little patience with "serious literature, serious political debate, serious ideas, serious anything" (Gabler, 1998, p. 9). At risk is what Kermode (1996, p. 32) called "the highest pleasure, the pleasure of complexity," which is an acquired taste.

The ascendance of an image-rich mass entertainment culture might correspond to a decline in high-level verbal processing ability. Exposure to television can produce gains in word knowledge, but only to a point. Television vocabulary seems to top out at about the fourth-grade level; for a child to make gains beyond that

seems to depend on significant exposure to more complex forms of language, especially as found in text. This is true partly because the kind of language used in the mass media is poor not only in vocabulary, but also in syntax. Mass media syntax is typically simple, consisting mostly of incomplete sentences that depend heavily on the presence of an image for comprehension of meaning. That is, TV and allied media do not present the kind of context-independent and explicit kinds of language that readers of text must rely on to construct, mentally, a model of what is being described. Unfortunately, and probably partly because of a shift to iconic mass media, there is less incidence of book reading than there has been in the past. Greenfield (1998) blamed the decline in high-level verbal ability, as manifest in SAT scores, on this shift toward nonprint media. Thus, iconic media may have mixed effects on verbal ability—raising the floor, but lowering the ceiling.

8. Ensure That, for All Children, Nutrition Is Optimized and Exposure to Toxins is Minimized. The cumulative research on nutrition and cognition has established a linkage between the two. In fact, global improvements in nutrition during the 20th century may have contributed to the worldwide increase in IQ known as the *Flynn effect*. That nutrition has played some role in the Flynn effect is supported also by the finding that smaller-scale nutritional improvements tend to enhance spatial or fluid abilities more than verbal abilities, a pattern that corresponds to the global pattern of rising cognitive abilities (Flynn, 1996).

In several experimental studies, vitamin and mineral supplementation resulted in cognitive gains. In developing countries, protein supplementation in childhood produced cognitive benefits lasting into adolescence and early adulthood. In New York City schools, attempts to improve the nutritional quality of foods led to discernible increases in school achievement. Although the agenda of cognitive enhancement must engage symbol processing activity, a healthy neurological base is a prerequisite. These findings warrant that every child should be assured of a daily nutrient intake defined not by what is minimal, but by what is optimal. The level of a particular nutrient that would prevent a deficiency disease, such as rickets or night blindness, may be different from the level that is ideal for health and cognitive growth. We should ensure that all children, especially those raised in poverty or inadequate social conditions, receive optimal levels of vitamins, minerals, protein, and other essential nutrients, and are spared exposure to toxins. Otherwise, a malnourished child might display apathy or irritability, and thus be unable to evoke sympathetic responsiveness from adults, leading to a cycle of interactional deprivation (Chávez & Martínez, 1975; Joffe, 1982).

The Workplace

9. Reconceptualize the Workplace as an Educational Institution. I have emphasized that nonschool learning environments are at least equal in importance to formal education in cognitive development (Ralph, Keller, & Crouse, 1994).

Educative environments include families, but also other settings, such as the workplace. General cognitive ability is relevant not only to what occupations are open to the individual—IQ has repeatedly been shown to predict workplace performance within jobs. The predictive validity of IQ on job performance is strongest when jobs are organized according to "complexity family" such that IQ best predicts proficiency in symbolic-analytic occupations. Given the connection between cognitive ability and workplace productivity at the level of the individual worker, it is necessary to reconceptualize the workplace as a facilitator of ongoing cognitive development; that is, as an educational institution in its own right (Secretary's Commission on Achieving Necessary Skills, 1991).

The connection between workplace activities and the growth or decline of cognitive abilities was established decades ago. Vernon (1948, p. 138) found, for example, that intelligence decreased for men in "lower-grade" occupations, but was maintained for those involved in "intellectual" occupations. More recently, Kohn and Schooler (1973; Schooler, 1998) found that workers whose jobs were intellectually challenging and entailed self-directed complex work developed greater intellectual flexibility, independent of workers' education level, than did less intellectually challenging jobs. Kohn and Schooler (1973) also found that the substantive complexity of jobs is related to positive feelings about work and toward self, even when controlling for other job characteristics and workers' education.

Work experience can lead to changes in cognitive abilities composing intelligence, including the capacity to deal with complex problems expressible in symbolic terms. It is just these abilities that have been recognized as central to worker effectiveness in the future. Hunt (1995), in analyzing trends in societal composition and the demands of the future workplace, concluded that what is needed most in the American workforce are problem-solving abilities and "learning to learn" skills, competencies that happen to map onto fluid and crystallized intelligence, respectively. United States government panels on the demands of the future labor market have arrived at similar conclusions, noting that learning and problem-solving skills are essential to the future workforce (Commission on the Skills of the American Workforce, 1990; Secretary's Commission on Achieving Necessary Skills, 1991).

Predictors of workplace success go beyond IQ. For example, certain personality dimensions of the "Big Five" theoretical model correlate with workplace performance (Landy, Shankster, & Kohler, 1994).[3] In particular, the superfactor known as *conscientiousness* predicts job performance quite widely, especially among workers whose jobs permit autonomy (Barrick & Mount, 1993). The conscientiousness dimension describes workers who are achievement oriented, responsible, and persistent. Conscientiousness and IQ are statistically independent; the combination of IQ and conscientiousness (and related measures of integrity) yields the best-known prediction of workplace performance (multiple $r = 0.65$) from two variables (Schmidt & Hunter, 1998).[4] Another predictive personality dimension, also one of the five superfactors, is *agreeableness* (Tett, Jackson, &

Rothstein, 1991). United States government reports have called for skills that can be collectively referred to as a "work ethic," which include the ability and commitment to meet deadlines and to do better work than is minimally necessary (Hunt, 1995). Under the broadest construal of intelligence, these characteristic behavior patterns might be included. Likewise, they too might be cultivated strategically in work settings.

There is another hugely important resource in determining workplace performance, and that is relevant knowledge. In terms of Cattell's fluid/crystallized intelligence dichotomy, domain knowledge is located on the crystallized side. Cognitive research has shown that the highest levels of performance in any domain rely on an extensive, well-organized knowledge base. Simon (1991) advanced parameters on the information-processing prerequisites of world class performance: 50,000 or more "chunks" of knowledge acquired over at least 10 years of full-time study. The importance of knowledge to the international economy was recognized by Stewart (1997), who called it the "primary ingredient of what we make, do, buy, and sell" (p. 12). Over the life span, as adults become invested in diverse roles requiring diverse funds of knowledge, broad-scale crystallized intelligence becomes less meaningful as a psychological construct (Ackerman, 1996). It is not that knowledge becomes less important over a lifetime; to the contrary, it is more important than ever to the development of expertise, but its contours become narrower and much deeper.

The Nation

10. Identify the Cultivation of Intelligence as a National Education Priority. Given more than a century of research on intelligence, it is somewhat surprising that only one nation has ever tried to raise the intelligence of its citizens. In the early 1980s, Venezuela adopted the cultivation of intelligence as a national goal, and that decision led to the short-lived, although successful, Project Intelligence. Given our understanding of how intelligence develops, and the importance of intelligence to individual and collective success, it is past time to develop what is arguably the most empowering technology of all—the technology of learnable intelligence. Recognition of this goal at a national level, followed by allocation of resources to achieve it, would help ensure a more strategic approach than that obtainable through many independent and uncoordinated efforts.

CONCLUSION

Although intelligence has long been regarded as inherited and immutable, the research evidence no longer supports that view. Experience plays a major and necessary role in the development of intelligence, and can account for much existing variation in IQ, including mean differences between racial/ethnic groups. Carroll (1997) spoke of these differences as, in part, "the resultant of opportunities afforded by schools, families, and everyday experiences" (p. 47). This realization opens the possibility that experience can be designed to encourage the growth of intelligence. Research has helped to make this possibility realizable through the analytical characterization of intelligence as definable competencies—a learnable repertoire (Perkins, 1995; Schank, 1986; Snow, 1996; Staats & Burns, 1981). Although there are dissenters and skeptics (e.g., Eysenck, 1998; Spitz, 1986), there is now an impressive accumulation of data showing that intelligence is definable and malleable. Cognitive psychology has contributed to this interpretive shift. Within the cognitive paradigm, it is now possible to define intelligence in terms compatible with information-processing models of the mind—namely, that intelligence consists in the variegated cognitive functions that facilitate effectiveness not only in formal education settings, but also in real-life problems and creative accomplishment. Traditional cognitive abilities—the kind studied by psychometricians—are implicated, but so are many other abilities, such as the complex and time-extended phenomena of problem solving and problem finding.

NOTES

1. The goal of education had long been viewed as the training of intellect in a generic sense, and only in the 20th century has this idea been questioned (Snow, 1982b). However, from antiquity to the beginning of the 20th century, intellectual development was thought to be accomplished through the exercise of mental faculties, much like physical strength is developed through the exercise of muscles. The rigor and complexity of Latin and other "disciplines" were thought to discipline the mind in a general way. It was assumed that this generic strength carried over, or transferred, to other intellectual pursuits, even those that were substantively remote. The transferability of Latin itself was cast into doubt when Thorndike (1924) published a paper showing that the study of Latin conferred no advantage to students' achievement in other subjects (however, cf. Judd's (1908) neglected rejoinder that far transfer is possible when the learner truly understands). This was the first step toward the demise of faculty theory and to a consensus of pessimism about transfer and the idea that education could develop general cognitive abilities.

2. Causal relations between education-adjusted vocabulary and reading habits cannot be proven by these data. However, deviations from linearity (i.e., residuals) between these variables and period of birth are correlated, adding support to a causal interpretation (Glenn, 1994).

3. The "Big Five" personality superfactors are extraversion, neuroticism, conscientiousness, agreeableness, and openness (Bouchard, 1994). These factors have been called by different names in different theories of personality.

4. The multiple correlation of IQ and conscientiousness to performance applies across a wide range of job types. The correlation is probably higher for the symbolic-analytic worker, because the predictive validity of IQ rises with job complexity and, similarly, the predictive validity of conscientiousness increases for jobs involving greater decision-making discretion.

1

The Age of Intelligence

In the fast-paced, technology-dense world indwelled by much of the earth's population, the supreme human resource is intelligence. That is because intelligence consists of the knowledge, skills, and strategies necessary to be effective in a world that is complex and information-rich, a world in which daily life consists largely in a concatenation of problems to be solved. Intelligence shapes the economic prospects of individuals, organizations, and nations. Intelligence also connects to the causes and potential solutions of deep-rooted social problems. My thesis is this: The intellectual abilities that are crucial to modern life, including economic viability and effectiveness in daily living, correspond to the cognitive functions that are reasonably called *intelligence*. Moreover, those intellectual abilities are learnable.

This differs radically from the conventional view that intelligence is invariant and determined by heredity. In this book, I present evidence that intelligence is not an innate, immutable, and strictly inherited capacity, but instead is a repertoire of learnable cognitive functions. And although genetics does have a role in shaping intelligence, the acquisition of competencies composing intelligence depends profoundly on experience. Tremendous economic and social implications follow. Most fundamentally, it becomes possible to reconceptualize the goals of education to embrace the cultivation of intelligence, and to redefine education as consisting in all those experiences, through the life span, that lead to its enhancement.

INTELLIGENCE AND THE ECONOMY

The rising importance of intelligence to work is demonstrated in the way that economists have redefined the job sectors composing the labor market. Long-recognized distinctions in the labor market—especially between "white-collar" managers and "blue-collar" laborers—are giving way to divisions that recognize the importance of intellect to contemporary work. One alternative typology of jobs was set forth by Reich (1992), who divided the labor market into three sectors: symbolic-analytic workers, in-person workers, and routine production workers (cf. Stewart, 1997). In modern economies, the most important and rewarding of these is the symbolic-analytic sector, which comprises workers who specialize in "problem solving, problem-identifying, and strategic-brokering" (Reich, 1992, p. 177). The symbolic analyst is a professional problem solver whose work consists of tasks that are novel and complex, that resist routinization, and that entail the

gathering and transformation of information in symbolic form. These task characteristics—problem solving, complexity, and symbolic information—have strong associations with the qualities of thinking collectively called intelligence.

The division of the labor market proposed by Reich explicitly recognizes the importance of intellect to work. Likewise, a U.S. government report on workplace skills needed for the 21st century called for a "new set of competencies" that are predominantly cognitive. These "new" competencies include a foundation of literacy and personal skills, but also such thinking skills as problem solving, reasoning, and decision making—the "true raw materials" from which workplace competency is now built (Secretary's Commission on Achieving Necessary Skills, 1991, pp. vi, 17). More technical analyses also support the view that contemporary jobs can be differentiated according to their cognitive demand. In a factor analysis of jobs in the petrochemical industry, Arvey (1986) found that a "judgment and reasoning" factor accounted for almost half of the common variance in job similarity ratings.[1] This factor, according to Arvey (1986) "corresponds quite well to a general [intelligence] *g* factor" (p. 418). In another study, Hunter and Hunter (1984) found that the key organizing dimension of diverse jobs was their complexity. These analyses are consistent with the intuitive categories proposed by Reich, and with the hypothesis that both people and jobs can be compared along a similar intelligence axis.

The importance of intelligence to contemporary work is also demonstrated by the power of intelligence, measured as IQ, to predict job performance. It is important to note that the terms *IQ* and *intelligence*, although often used interchangeably, are in fact not identical in meaning. The difference is that IQ is a rough approximation, a convenient stand-in, for the diverse collection of powerful cognitive competencies to which we give the name *intelligence*. Whereas IQ is a test-based metric expressed as a single numeric value, intelligence is the underlying construct that is so complex it may never be understood completely. As a test-based metric, IQ is never a perfect predictor of job performance, and in some cases it is only a mediocre predictor (Wigdor & Green, 1991). However, it is hard to find a better one. Of all personal traits studied, IQ predicts workplace performance best (Schmidt & Hunter, 1998). The predictive power of IQ is strongest when correlations are "corrected" statistically (or disattenuated) for the imprecision of the job performance measure and for restriction of ability range.[2] Over a wide span of occupations, the mean predictive validity (disattentuated) of IQ on job performance is about 0.51 (Schmidt & Hunter, 1998).

The predictive validity of IQ increases as jobs become more complex (Hunter, 1986; Hunter & Hunter, 1984). In one study, the range of disattenuated validity coefficients extended from 0.23 for low-complexity jobs to 0.58 for high-complexity jobs (Gottfredson, 1997; Schmidt & Hunter, 1998). Hunter and Hunter (1984) obtained similar results: Correlations between cognitive tests and job performance ranged from 0.27 to 0.61, with higher validity coefficients associated with more intellectually demanding jobs.[3] These studies suggest that it is possible to order

jobs, job families, and job holders along a cognitive dimension defined by information-processing complexity, and that this dimension can account for variation among jobs in their demand qualities, as well as variation among people in job success (Arvey, 1986).

INTELLIGENCE, EDUCATION, AND ECONOMIC REWARD

IQ tests were not originally designed to predict workplace performance. The first intelligence tests, devised about a century ago by the Frenchman Alfred Binet, were constructed for the purpose of predicting success in school. Commissioned by the Paris public school system, Binet invented IQ tests to separate failing students into two groups: those who had the ability to succeed in regular classes and those who were mentally challenged and needed special instruction. IQ proved to be effective in making that distinction, and continues to be a successful, although not perfect, predictor of academic success, correlating about 0.50 with academic achievement (Brody, 1992; Hunt, 1995; Neisser et al., 1996).

Why should IQ have any predictive power at all in forecasting success—career or academic? The answer is that it is not IQ (the number) that is important, although IQ-like tests clearly do function as socially important screening devices, but instead that IQ quantifies a more functionally relevant set of cognitive competencies that make success possible. When intelligence is viewed as a set of competencies, the implication is that intelligence also can be learned. That is, intelligence is not just an *input* to education, but also an *output*, or product, of educational experience (Snow, 1982a). When Binet invented the first IQ test, he saw intelligence as an important input to education in that students who were more intelligent (i.e., had higher IQs) were more likely to succeed. Since Binet's time it has become clear that intelligence is equally a product of education or, more exactly, of all experiences that have educational value. Actually, Binet himself understood this quite well. This view of intelligence—as a product of experience—sharply contrasts with preconceptions of intelligence as invariable and as determined by each person's DNA code.

One potent form of experience in engendering the cognitive competencies associated with intelligence is formal education. Reich (1992) regarded a university-level education as a crucial phase in the development of the symbolic analyst. The investment reaps rewards: College and postbaccalaureate education greatly increase the likelihood of high pay. Moreover, the wage premium that accompanies higher levels of education is growing. In 1979, the average annual pay for a "prime age" (30 to 59) male high school graduate was $37,800, and for the holder of a bachelor's degree, $53,600 (in constant 1996 dollars; Carnevale & Rose, 1998). Just 16 years later, in 1995, the annual earnings of the high school graduate dropped 18% to $31,000, whereas for the college graduate annual earnings rose 10% to $58,700.[4] In other words, during this 16-year period, the wage premium for a college

education over a high school education more than doubled, rising from 42% to 89%. Table 1.1 illustrates the association of income with formal education. Representation in the wealthiest quintile rises sharply with education level. The negative slope associated with the poorest quintile tells the reciprocal story. Opportunities for work success drop off steeply with lower levels of education, so much so that by the 1990s "low skill level" could be reasonably interpreted to mean no college experience (Carnevale & Rose, 1998; Hunt, 1995).

In the future, prospects for economic reward are likely to depend even more on the type of work in which one engages. The reason for this, according to Reich (1992), is that the economy has evolved to the point where "the value of new designs and concepts continues to grow relative to the value placed on standard products," and because of this "the demand for symbolic analysts will continue to surge" (p. 225). This trend places some workers at risk. Routine production workers will find themselves increasingly confined to low-wage jobs and vulnerable to replacement by machines. This is the case even now. Robots are displacing workers whose jobs can be reduced to a sequence of movements controlled by machine actuators. And, increasingly, robots can be programmed to produce short runs of customized products demanded by consumers. Thus, despite the economic transition from high-volume manufacturing to low-volume customization, robots threaten to displace workers whose primary skill is the routinized manipulation of materials (Hunt, 1995). Compounding this economic jeopardy, the globalization of commerce means that routine production workers must now compete with workers in developing countries—workers whose costs of living are much lower and who are quite happy to work for a fraction of the American minimum wage (Reich, 1992).

TABLE 1.1
Educational Attainment and Income Quintile Within the United States:1995

	Income Quintiles	
Education Level Attained	*Lowest*	*Highest*
9th to 12th grade (no diploma)	39.9	5.0
High school graduate	19.5	11.9
Some college, no degree	15.6	18.5
Associate degree	11.0	21.4
Bachelor's degree	6.1	39.2
Master's degree	4.2	51.9
Professional degree	3.6	66.3
Doctorate degree	2.2	61.2

Note. Adapted from *Statistical Abstract of the United States* (p. 470; Table 726), by U.S. Department of Commerce, 1997, Washington DC: US. Author. Public Domain.

Although global economic evolution portends a dire future for routine production workers, opportunities for symbolic-analytic workers will continue to expand. Where will this lead? According to Herrnstein and Murray (1994), the divergence of opportunity paths has already produced a two-tiered society, segmented into a "cognitive elite" and a cognitive underclass. The division arises from the compounding prosperity of an insular cognoscenti—Reich's symbolic analysts—and the economic descent of the routine production laborer. Although there is disagreement among economists about the degree and seriousness of the cognitive-economic rift in American society, the fact of increasing social fractionation along economic lines is not disputed.

INTELLIGENCE AND SOCIAL PROBLEMS

In the foregoing paragraphs, I drew a conceptual triangle whose corners are intelligence, education, and economic reward. A fourth concept, already implied, is the vast arena of social problems. Social problems are of course multidimensional, but one especially salient dimension is the perennial inequality associated with race and ethnicity. Inequality is manifest in marked differences between racial/ethnic groups in academic opportunity and attainment, occupational achievement, health, and physical safety. These differences are yoked to income inequalities. Among the wealthiest fifth of Americans, by annual income, White families have two to three times the representation of African American and Hispanic families. At the other end of the economic spectrum the pattern is reversed: African American and Hispanic families have more than double the representation of White families among the poorest fifth (U.S. Department of Commerce, 1997). Although African American families, and to a lesser degree Hispanic families, have gained representation among the wealthy, the median income of White families has been rising even faster (U.S. Department of Commerce, 1997).

Race-based inequalities are manifest in measures of symbolic-analytic attainment (i.e., cognitive test scores), and in experiences that produce symbolic-analytic ability (i.e., formal education). And yet, within groups, the functional associations among cognitive ability, education, and economic reward are comparable: Those who have higher levels of cognitive ability are rewarded economically, regardless of race. This has not always been the case. In the 1960s, the earnings of African American workers who scored high on cognitive tests were only about two thirds that of White workers who obtained comparable scores. But by the mid-1990s, the average income of high-scoring African American workers was at 96% that of Whites (Jencks & Phillips, 1998a, 1998c). If cognitive test scores approximate intellectual readiness for effectiveness in a complex world, then "raising black workers' test scores looks far more important than it did in the 1960s" (Jencks & Phillips, 1998a, p. 46).

Intelligence can purchase economic rewards for individuals, organizations, and nations. It may even help explain social inequalities associated with race. But the importance of intelligence to social outcomes extends further. At issue is survival. The supreme social conundrum, which has been called *the world problematique*, is the tangle of world problems bearing on the survival and safety of all living things, and includes the nightmare of nuclear annihilation and the threat of a poisoned biosphere (Botkin, Elmandjra, & Malitza, 1979). The enormity of world problems has long been recognized; what is new is a reconceptualization of the root cause of those problems and where to look for answers. Until recently, serious world problems have been managed tactically as crises. A conceptual turning-of-the-corner is recorded in the document *No Limits to Learning*, also known as the Club of Rome Report, which presents the crux of the world problematique as essentially a *human* problem (Botkin et al., 1979). To pinpoint the difficulty, it arises from the gap between the increasing complexity of problems faced by humanity and the human capacity to understand and solve those problems. That is, the origin and center of the world problematique is not "out there" in the world, but instead lies within. Its cause and solution are human and, substantially, cognitive. The Club of Rome Report invites the reader to lay aside assumptions about what constitutes a normal course of education, and to trade those in for "an entirely new enterprise" that recognizes the human mind as the key to both averting disaster and building a better world (Botkin et al., 1979, p. xv).

RECONCEPTUALIZING EDUCATION

Both economic rewards and social problems are linked to symbolic-analytic ability, which I identify with intelligence. Intelligence, in turn, is presented as a set of learnable competencies whose cultivation depends on experiences of high quality; that is, experiences that merit the descriptor *educational*. A programmatic implication is that the purpose of education could be recast to include the development of intelligence as a primary goal. By definition and by intention, intelligence could become a conceptual integration point for the purpose and design of all educational experiences and a standard for judging the quality of experience.

For many people, the idea that education could be concerned with the cultivation of intelligence is counterintuitive. Even for many psychologists, the term *intelligence* implies a monolithic and static ability that is genetically preset. Without saying that genetics is irrelevant to intelligence—it is not—there now exists a large body of data showing that experience (i.e., "nurture") plays a powerful role in the development of the intelligent human being. Not only data, but also new theory, especially cognitive information-processing psychology, have recast intelligence as consisting of learnable competencies that can be cultivated through experience. Binet himself saw intelligence as malleable through instruction, and *cultivation* was exactly the metaphor he chose to describe how intelligence could be taught, with the expectation of a rich harvest (Cronbach, 1984).

What is intelligence? As a first approximation, I define intelligence as a repertoire of learnable cognitive competencies that permit effectiveness in a complex, symbol-rich, and problem-oriented world. Of course, intelligence is much more than that. Concise definitions of complex phenomena, although useful as points of departure, necessarily oversimplify. This is the case with intelligence, partly because it is multifaceted, but also because differing theoretical perspectives have been applied to intelligence over the century or so that it has been studied seriously. Although these differing paradigms are often cast as competitors, they are more productively viewed as complements that together present a fuller picture than any single perspective (Sternberg, 1990a). Multiple points of view also permit intelligence to be described in terms that are comprehensive enough to explain interconnections with social outcomes, yet precise enough to say how experience can be designed to favor the inculcation of the intelligence repertoire; that is, to say how intelligence can be cultivated.

NOTES

1. Loading heavily on this factor were the job descriptors: "deals with unexpected situations," "able to learn and recall job-related information," and "able to reason and make judgments."

2. Correction for restriction of range is justified because successful applicants (or "incumbents") display less variation in job performance than would all applicants, if hired. Predictive validity should be descriptive of the entire applicant pool rather than the incumbents only.

3. Some writers have estimated the predictive validity of IQ to be much more modest, approximately 0.2, when variables are not corrected for unreliability or range restriction (Sternberg, 1996b). However, correction for restriction of range is defensible because the utility of IQ measures for personnel selection should be based on the total applicant pool, not the subset of those hired (see note 2). Correction for unreliability is more questionable, but can be seen as important if the objective is to estimate the *theoretical* importance of the aptitude (intelligence) to the criterion (worker success), in contrast with real-world selection based on test scores. Whether corrected for unreliability or not, the moderate correlations imply that factors other than IQ are at work in shaping workplace success (Sternberg, 1996b). Nonetheless, it is likely that each job has an associated requisite mental ability that permits acceptable performance. Above that threshold, other personal qualities contribute to superior performance (Hunt, 1995).

4. A comparable trend is found for female workers. During the same period (1979 to 1995), the wage premium for women with a bachelor's degree over those with a high school diploma rose from 56% to 87%.

4

Emergent Models

The information-processing perspective transformed intelligence theory because it led to a more molecular view of intelligent functioning than was possible within the psychometrician's theoretical framework. Information-processing psychology helped researchers identify the cognitive elements of intelligent functioning and describe their operations and interactions. Yet, to many investigators, the reconceptualization of intelligence did not go far enough. It still seemed to have a narrow quality, partly because it was often aimed at explaining those information-processing competencies that facilitate success on tests of cognitive ability—hardly ends in themselves. The parochial quality of the psychometric paradigm was largely inherited by cognitivists because they, too, restricted the phenomena of interest to a rather narrow range of tasks and contexts (Cattell, 1987).

For cognitivists, the initial concentration on psychometric tests was defensible because it connected their efforts to the instruments that for nearly a century had been the basis of serious theoretical and empirical work on intelligence. Tests had become (and still are) the most accepted way of operationalizing intelligence and its quantification as IQ. Also, cognitive tests *do* predict real-world attainments with moderate success, even though considerable residual variance remains unexplained. The variance in valued outcomes not absorbed by psychometric tests hints that mechanisms other than those captured by IQ tests are at work, and some of these might legitimately be considered aspects of broad-sense intelligence. In the language of this book, the intelligence repertoire is larger than that evoked by IQ tests or quantified in IQ scores.

In response to limitations in the range of phenomena studied in the psychometric and cognitive paradigms, other approaches to intelligence have emerged. These approaches have led to a greater appreciation of an expanded range of functions constituting intelligence, the range of performances recognized as intelligent, and the relevance of context and culture. New research methods, including brain imaging, also contribute to a more complete understanding of intelligence. A sampling of these emerging perspectives is reviewed in this chapter.

GARDNER'S THEORY OF MULTIPLE INTELLIGENCES

The best-known contemporary model of independent abilities is Gardner's (1983) theory of multiple intelligences. Gardner proposed the existence of eight "relatively autonomous" intelligences: linguistic, logical-mathematical, spatial, musical,

bodily-kinesthetic, interpersonal, intrapersonal, and naturalist (Gardner, 1983, p. 203; Gardner, Kornhaber, & Wake, 1996). A brief description of each of the intelligences is presented in Table 4.1. In addition to these, Gardner (1997) left open the possibility of additional intelligences, such as an "existential" intelligence identified by deep concern with and insight into questions of meaning and existence. In proposing separate intelligences, Gardner rejected the idea of a unifocal *g* that cuts across disparate forms of cognitive functioning. This conceptualization of intelligence is "Thurstonian" in orientation, although not in methodology. Multiple intelligences (MI) theory can be seen as a modern-day version of the independent factor theories of E. L. Thorndike and Thurstone in the early 1900s, but is based on a different set of epistemological tools.

In a considerable break from past epistemologies used to understand intelligence, Gardner conjoined methods and findings from several disciplines to construct a theory that has broadened traditional accounts of what constitutes intelligence. Gardner drew from many data sources, but primary among these is the neurological phenomenon of selective impairment. In brain-injured patients, cognitive impairments are sometimes circumscribed such that other cognitive abilities retain normal functioning. For example, a brain injury might disrupt musical competence but leave logical, language, and other functions unharmed; if so, Gardner would take this as evidence for the neurological independence of musical intelligence. The selective impairment methodology assumes that intelligences can be mapped onto different regions of the cerebral cortex, and in fact Gardner found some evidence for the anatomical separability of intelligences (Gardner & Hatch, 1989).

Another stream of evidence for MI theory is the variety of adult roles and, especially, the expert end-states valued by cultures. A poet, for example, is the apotheosis of linguistic intelligence; a sculptor displays a honed form of spatial intelligence. The existence of cross-cultural differences in the relative valuation of intelligences is yet another line of evidence for Gardner's distinctions. For example, Gladwin's (1970) study of sea navigation in Micronesia demonstrated how a focused ability (spatial) can be indispensable to achievements of high prestige within a culture. The master navigators of the Puluwat atoll can steer an outrigger sailing canoe over hundreds of miles of open ocean. To do this, they rely on a system of celestial navigation of their own invention, and pass on the secret knowledge of sea navigation only to those young men who are invited into the guild.

Two peculiar kinds of expertise are the conspicuous talents of prodigies and idiots savants. To Gardner, the existence of children who develop impressive levels of musical talent precociously is evidence for the independence of musical intelligence. Among idiots savants, functioning is uniformly *sub*normal except in the focal area of talent. For example, some idiots savants (or autistic savants or simply savants), having heard a complex musical piece only once, may be able to reproduce it flawlessly on a piano (Sloboda, Hermelin, & O'Connor, 1985). Yet,

Table 4.1
The Eight Intelligences

Intelligence	*End-States*	*Core Components*
Logical-mathematical	Scientist, mathematician	Sensitivity to, and capacity to discern, logical or numerical patterns; ability to handle long chains of reasoning
Linguistic	Poet, journalist	Sensitivity to the sounds, rhythms, and meanings of words; sensitivity to the different functions of language
Musical	Composer, violinist	Abilities to produce and appreciate rhythm, pitch, and timbre; appreciation of forms of musical expressiveness
Spatial	Navigator, sculptor	Capacities to perceive the visual-spatial world accurately and to perform transformations of one's initial perceptions
Bodily-kinesthetic	Dancer, athlete	Abilities to control one's body movements and to handle objects skillfully
Interpersonal	Therapist, salesperson	Capacities to discern and respond appropriately to the moods, temperaments, motivations and desires of other people
Intrapersonal	Person with detailed, accurate self-knowledge	Access to one's own feelings and the ability to discriminate among them and draw on them to guide behavior; knowledge of one's own strengths, weaknesses, desires, and intelligences
Naturalist	Botanist, geologist, archaeologist	The ability to distinguish among, classify, and use features of natural and artificial environments

Note. From "Multiple Intelligences Go to School: Educational Implications of the Theory of Multiple Intelligences," by H. Gardner and T. Hatch, 1989, *Educational Researcher, 18*(8), p. 6. Copyright 1989 by the American Educational Research Association; reproduced with permission from the publisher. The description and end-states for the last-listed intelligence, naturalist, are taken from the Project SUMIT website (http://pzweb.harvard.edu/SUMIT/MISUMIT.HTM) and Gardner , 1997.

the savant is no genius—typically, his or her "expertise" is inflexible and unoriginal.[1] Nonetheless, the stunning prominence of a single ability against a field of general impairment was seen by Gardner as evidence for the independence of its referent intelligence.

As further evidence for independent intelligences, Gardner cited the module-based development of symbol systems used to represent and communicate ideas. For musical and linguistic intelligence, these symbol systems are obvious: musical notation and written language. Logical-mathematical intelligence is supported notationally by an elaborate system of symbols, equations, and operations. Other intelligences have lesser-known symbol systems or none at all, but according to Gardner the generation of a supportive symbol system is only a tendency, not a requirement.

Gardner's theory of multiple intelligences is significant methodologically and theoretically because it reaches beyond the parochiality of much psychometric and cognitive research on intelligence. Cattell (1987), in a frank commentary on his own methodology, admitted that psychometrically defined intelligence has been "systematically biased" and "sadly uninformed by imaginative safaris into new areas" (p. 128). Gardner's theory goes a long way toward remedying this bias. MI theory also has practical implications. Schooling and Western culture generally are strongly skewed toward certain kinds of intellectual expression, especially linguistic and logical-mathematical intelligence. Other aspects of intelligence are neglected or ignored, possibly squandering talent. To the degree that educational systems can recognize and develop the full range of abilities represented by diverse intelligences, individuals—indeed, all of society—will benefit.

Yet is MI Theory really so different from what psychometrically oriented researchers proposed long ago? Psychometric theorists have long acknowledged that *g* cannot tell the whole story of intelligence, and that subordinate group factors certainly exist (Boring, 1923). These factors might be sensibly described as "relatively independent," because their degree of covariation is moderate (but real). In fact, at least three of Gardner's intelligences—logical-mathematical, linguistic, and spatial—can easily be mapped onto the psychometric hierarchical model because these three identify major group factors that have been recognized since the time of Thurstone.[2] Even interpersonal intelligence and musical intelligence have identifiable counterparts in the psychometric tradition. According to Eysenck (1998), "It is difficult to understand what Gardner is saying that is not covered by the orthodox hierarchical model" (p. 109).

As Eysenck implied, Gardner was justified in highlighting group factors, because a theory of *g* alone could never be a complete theory of intelligence (however, cf. Jensen, 1998). What Eysenck's comment missed is that Gardner made the much bolder claim that general intelligence is not warranted as a scientific construct. On Gardner's proposal—that multiple intelligences are both autonomous and sufficient—research spanning decades speaks to the contrary. Hundreds of

data sets have revealed substantial covariation among logical, linguistic, and spatial abilities. Gardner's own data are mixed on the question of autonomy. Although one study showed a modest degree of statistical independence among intelligences, another study revealed substantial intercorrelation (Gardner & Hatch, 1989). In Project START, Callahan and colleagues conducted a factor analysis of four MI-based scales, finding support for the validity of logical-mathematical and linguistic scales, limited support for a spatial scale, but no support for an independent interpersonal intelligence (Callahan, Tomlinson, Moon, Tomchin, & Plucker, 1995). In a more direct test of MI theory using confirmatory factor analysis, Callahan et al. found that the data conformed better to a hierarchical model than to an MI model of uncorrelated latent variables.[3]

Does *g* exist? On this question, some of the data cited by Gardner actually support an affirmative answer. Whereas most of Gardner's intelligences can be identified with specific areas of the brain, logical-mathematical ability is anatomically diffuse, spread over a large region of the cortex. Logical-mathematical ability seems to correspond functionally to the general mental ability factor identified by psychometric researchers, and its anatomical diffusion may reinforce claims for its functional generality (Gustafsson & Undheim, 1996; Messick, 1992). Gardner himself acknowledged uncertainty about the independent status of logical-mathematical ability, owning that it might be "some kind of supra- or more general intelligence" (Gardner, 1983, p. 159). His more recent description of logical mathematical intelligence as the ability to appreciate and use abstractions made the comparison with general mental ability even more direct (Gardner et al., 1996).

According to Messick's (1992) critique of MI theory, Gardner used psychometric evidence selectively in highlighting data that support the existence of separable intelligences, but downplaying evidence for their common variation. Gardner suggested that common variance among mental ability tests, which is evidence for *g*, is an artifact of tests' reliance on "skill in taking short-answer, paper-and-pencil tests" (Gardner et al., 1996, p. 213). However, this proposal seems weak. First, it does not explain relations exhibited within hierarchies both horizontally (similar abilities cluster) and vertically (higher factors involve more general functions related to abstraction, complexity, and the induction of pattern). Second, it is not intuitively compelling that a century's worth of predictive associations between IQ and educational, job, and social outcomes can be chalked up to individual differences in test savvy. Third, it is simply not true that tests of cognitive ability are always confounded with paper-and-pencil administration—many of the better-known intelligence test batteries involve performance or spoken responses by examinees. The weight of evidence for a hierarchical organization of abilities far outweighs the evidence for autonomous abilities proposed in MI theory. The convergence toward a hierarchical model with *g* at the pinnacle, and with primary abilities serving to "define" *g* (Cattell, 1987), is all the more plausible because it arose from different theoretical starting points (e.g., Spearman's and Thurstone's). To Messick (1992), "The invoking of autonomous mental modules

as opposed to a hierarchical structure of abilities would appear to be simply counterfactual" (p. 371).

On this point, Gardner himself has equivocated. When addressing the issue of *autonomous* intelligences, Gardner (Gardner, Kornhaber, & Wake, 1996, p. 203) employed the hedge "relatively," leaving the reader unsure of what he meant. "Relatively autonomous" might well describe group factors in the hierarchical model—their intercorrelations are, after all, only moderate. But perhaps the issue was not really crucial for Gardner. Indeed, it seems that Gardner was less concerned with being a good Thurstonian with regard to the emptiness of *g* than with emphasizing the breadth of cognition and performances that can be called intelligent, and with recognizing that intelligent thought and behavior are profoundly embedded within cultures. On these counts, Gardner succeeded.

Despite these criticisms, Gardner's theory is a vital contribution to intelligence theory in many respects. Undoubtedly, MI theory has been good for education by emphasizing that students differ in important ways, and that those differences are relevant to instructional decisions. Equally important, Gardner challenged, with intellectual integrity and healthy consequence, the orthodoxy of the psychometric "establishment," whose adherents will, at times, candidly acknowledge the parochialism of their own framework and methodology (Anastasi, 1986). Gardner's expansion of constructs and research methods are major contributions to the study of human intelligence.

STERNBERG'S THEORY OF SUCCESSFUL INTELLIGENCE

Sternberg's (1996c) theory of successful intelligence posits the existence of three aspects of intelligence that operate jointly to produce success. In this theory, success is defined with respect to an individual's own standards and the sociocultural context. The theory is meant to expand traditional conceptualizations of intelligence by recognizing that individuals vary in many ways—not just in their IQ scores—that are relevant to personal success. The theory of successful intelligence recognizes *analytical* intelligence as the set of abilities associated with success in academic environments, and in solving abstract problems. Analytical intelligence therefore connects Sternberg's theory with traditional accounts of intelligence that correspond to proficiencies tapped by IQ tests.

Two other forms of intelligence, creative and practical, enlarge the meaning of intelligence and its power to account for diverse manifestations of success, as well as the corresponding diversity of human characteristics responsible for success. Practical and creative intelligence also have weaker statistical associations with SES and racial/ethnic background than does analytical intelligence (Sternberg, 1998c). *Creative* intelligence entails skills and attitudes that enable a person to transcend the existing order to produce something new and culturally significant.

According to Sternberg (1999), creative intelligence is manifest in problem situations that are relatively novel, especially those that require a person to escape the entrenchment of scripted ways of thinking and acting. Measures of creative intelligence correlate only weakly with analytic ability and, unlike analytical ability, creative intelligence does not appear to have much general or cross-domain utility, but rather is domain specific. This finding differs from much of the research literature in which creativity is simplistically presented as an expression of creative personality characteristics. True creativity depends on the accessibility of richly interconnected knowledge in the domain of creative work (Ochse, 1990; Simonton, 1996).

Finally, *practical* intelligence refers to competencies that produce success in real-life situations, such as in the home or on the job. It is manifest in a person's ability to adapt to, select, and shape real-world environments. As Sternberg operationalized practical intelligence, it often takes the form of tacit knowledge that is acquired incidentally through experience, rather than taught directly. This tacit knowledge might include unspoken rules or skills necessary for success, such as how to move up in an organization, how to gain favor, or how to shield oneself from the crossfire of office politics—hence, it has high adaptive value. There is evidence that people differ dependably in their propensity to pick up tacit knowledge of this kind in everyday settings. There is also evidence that the measures of practical intelligence, such as one designed for corporate managers, have low statistical associations with analytical intelligence but predict success in the workplace more readily than do conventional tests of intelligence.

Sternberg's constructs of creative and practical intelligence, although welcome expansions of broad-sense intelligence, are somewhat lacking in clarity and defensibility. One potential problem is that the strong domain dependence of creativity makes it difficult to see how creative intelligence conforms to any reasonable sense of *intelligence*, because the word *intelligence* implies something more general. Also, creative intelligence is described by Sternberg as being best measured by performance on tasks that are "relatively novel" (Sternberg, 1999). However, creativity seems less a reflection of task characteristics than of the responses to a task. Raven's Matrices are novel for many examinees, and yet it is difficult to interpret successful performance on the Raven as creative. On the other hand, a person might be presented with a very conventional task, such as washing dishes, and invent a highly creative solution to it. The key dimension would seem to be the nonentrenchment of the *solution*, not of the task itself. Finally, the strong association of tacit knowledge with practical intelligence seems puzzling. Competent performance in any realm—analytical, creative, or practical—might be supported by knowledge that is acquired incidentally and held in tacit form. For example, it is easy to see the metacomponents that steer analytical intelligence as largely tacit.

Sternberg saw the three forms of successful intelligence—analytical, creative, and practical—as being subserved by their own information-processing

components. The idea of components was elaborated in Sternberg's triarchic theory of intelligence (1985a), a theory that predates the theory of successful intelligence and is now subsumed by it. In developing the *componential* subtheory, Sternberg's ideas and research techniques helped shape inchoate processing theories of intelligence, partly by introducing analytic methods into a domain that had long been dominated by psychometric methods (see chap. 3). According to the componential subtheory, intelligent thought can be broken down into constituent processes that Sternberg called *components*. A component is a basic information process—a one-step transformation of information that requires a processing time on the order of seconds or fractions of a second. Reading a single word, for example, could constitute a component. The subtheory specifies that performance on even a single test item is psychologically complex, and that an analytic understanding of that performance can be gained from subdividing aggregate performance into steps.[4]

The *contextual* subtheory recognizes that what is called intelligent thought and behavior depends on the particular cultural context, a point that cultural psychologists have pressed for decades. The idea is that a person thinks and acts intelligently when behavior is adaptive or has survival value within a particular setting. Also, intelligence is not passive adaptation to the demands of that context, but can involve the selection and shaping of environments in "a process of reciprocal transformation with the environment" (Ochse, 1990, p. 216). Contextual intelligence includes tacit knowledge about the unwritten rules of success in a particular environment.

In the *experiential* subtheory, Sternberg proposed that intelligence is exercised most clearly in two seemingly opposite situations. The first is novelty, which requires adaptation through problem solving and insight (cf. Larson, 1990). This proposal is closely linked to the theory of fluid intelligence, which also recognizes effective functioning in the face of novelty as a sign of intelligence. At the other end of the experiential continuum, intelligence is also exercised when a person employs skills adeptly in familiar situations with little conscious effort. Sternberg (1985a) explained that "complex tasks can feasibly be executed only because many of the operations involved in their performance have been automatized. Failure to automatize such operations, whether fully or in part, results in a breakdown of information processing and hence less intelligent performance" (p. 71). It is therefore at the poles of the experiential continuum—extreme novelty and extreme familiarity—that intelligence is most clearly observable. The pole corresponding to familiar situations is satisfied by knowledge, skills, and schemas that have been automated. The novel end of the continuum depends more heavily on executive processes. Viewed another way, the subtheory recognizes the hierarchical arrangement of cognitive processes, and the complementarity of higher- and lower-level elements. The subtheory is *experiential* in that what is considered novel or familiar depends on the experiential history of the person.

Sternberg's theory of intelligence has evolved considerably over time, and there has been a major shift in emphasis from his earlier triarchic theory (componential, experiential, and contextual) to his more recent and more inclusive theory of successful intelligence (analytical, creative, and practical). The newer theory subsumes the older. For the reader of Sternberg's books and papers, it is sometimes hard to see how these various constructs relate to each other. Sternberg is now clear that he has only one theory of intelligence, the theory of successful intelligence. It is also fairly clear that all aspects of successful intelligence are subtended by cognitive components as modeled in the componential subtheory. Sternberg has had less to say, however, about the status of the contextual and experiential subtheories. One has the impression that they point to important aspects of human intelligence, and seem to map onto creative intelligence (task novelty) and practical intelligence (tacit knowledge, environment selection and shaping); but these earlier subtheories have receded to the theoretical wings, whereas other, presumably more explanatory aspects (i.e., creative and practical intelligence), have moved to center stage.

CONTEXTUALIZED INTELLIGENCE

The idea of contextualized intelligence gives due recognition to specific situational knowledge, whose importance has often been ignored in traditional theoretical accounts. Contextual theories reject the historical and everyday meaning of intelligence as cognitive capability that cuts across a wide swath of diverse situations. A generalized version of the context argument is that what is considered intelligent behavior depends on the particular culture within which thought and action occur. In non-Western countries, for example, people are sometimes more likely to classify common objects by function (e.g., knife goes with orange) rather than by taxonomic category (e.g., knife goes with fork), opposite to what a typical Western person would do. Glick's (1975) famous observation is pertinent here. Glick studied the performance of a Liberian Kpelle tribesman on a sorting task. Twenty items were laid out on the floor—five items each of food, clothing, tools, and cooking utensils—and subjects were asked to sort the items in a way that made sense to them (Cole, Gay, Glick, & Sharp, 1971). Glick (1975) recounted:

> When the subject had finished sorting, what was present were ten categories composed of two items each—related to each other in a functional, not a categorical manner. Thus, a knife might have been placed with an orange, a potato with a hoe, and so on. When asked, the subject would rationalize the choice with such comments as, "The knife goes with orange because it cuts it." When questioned further, the subject would often volunteer that a wise man would do it this way. When an exasperated experimenter asked finally, "How would a fool do it," he was given back sorts of the type that were initially expected—four neat piles with foods in one, tools in another, and so on. (pp. 635–636)

brain activity was distributed throughout the cortex, but that posterior regions of the brain (the parietal and occipital regions) were especially active. Even more interesting was the relationship between glucose metabolic rates and Raven performance. In particular, *higher* Raven scores were associated with *lower* rates of glucose utilization in the brain areas responsible for performance. High-performing subjects seemed to be more metabolically efficient. In studies such as these, empirically derived mind-brain connections help anchor information-processing models to brain physiology.

Still, caution is needed. It is easy to draw unwarranted inferences from brain research to conclusions about human learning. Perhaps the most serious conceptual error is to see neurological mechanisms as driving all cognitive activity. This view ignores causation in the other direction—from cognition to changes in neuronal structure and function (Sternberg, 1994b). Mind and brain reciprocate. The brain's "wetware" affords a physical and electrochemical substrate for the mind's dynamic patterning of symbols, or what Perkins (1995) called "mindware" (Shore, 1996). Consciously controlled strategic thinking might be more sensibly viewed as propagating *downward* to more elementary information processing, and from there to brain function, than seen as moving strictly upward from cells to strategy (Hunt, 1986). In an arguably revisionist rejection of reductive physicalism or "microdeterminism," Sperry (1995) proposed that cognitive science might be seen as a flag carrier for other sciences. Complex systems—whether the human mind or the path of a molecule in a rolling wheel—often exhibit behavior in which causal control is tenably described as being both top-down and bottom-up.

A top-down interpretation is reinforced by data showing that neurological structure is "sculpted" by experience (Nelson, 1999). At least two mechanisms are responsible for this environment-to-brain effect. In experience-*expectant* development, the experiences that are typical of a species stimulate the overproduction (or blooming) of neurons, and guide their selective elimination (or pruning; Greenough & Black, 1992). In contrast, experience-*dependent* development describes idiosyncratic changes in synaptic structure within the individual organism. The first process occurs early in life (in humans, up to adolescence) and defines normal brain structure; the second is functional through most of the life span and differentiates one organism from the next, reflecting the uniqueness of individual experience (Cotman & Neeper, 1996). In infrahuman species, enriched environments have been associated with greater numbers of synapses, increased vascularization, and enhanced glial cell support in brain regions corresponding to the environmental enrichment. Rapid and profuse dendritic branching as a function of enriched experience has even been observed in adult and "middle-age" rats at nearly the level observed in youngsters.

Brain plasticity appears to be mediated by a class of molecules known as *neurotrophins*. Neurotrophins, such as nerve growth factors, can induce the proliferation of neurons and increased brain vascularization. As organisms age,

neurotrophin levels tend to drop precipitously, but this is not inevitable. Neurotrophin levels rise in response to cognitive stimulation and physical exercise (Cotman & Neeper, 1996). Neurotrophins (NTFs) may also be responsible for the strengthening of neural pathways as a function of use. This process is illustrated in Figure 4.1. Panel A shows, in sequence, that the stimulation of a neuron can induce the production of neurotrophins, which are then sensed by the originating and adjacent neurons. The entire neural pathway is strengthened as a result. Panel B shows the larger context, namely that the organism's behavior, including learning and exercise, can stimulate the production of "plasticity factors," such as neurotrophins. The positive effects of neurotrophins on the system can lead to a second and more robust feedback loop in which the strengthened behavior induces the release of additional neurotrophins, leading to further neuronal enhancement.

Wachs (1996) saw the contrast between experience-expectant and experience-dependent development as helping to explain Scarr's (1992) contention that nonextreme or species-normal environmental variation is functionally equivalent, and therefore has little impact on normal development. Minimally sufficient

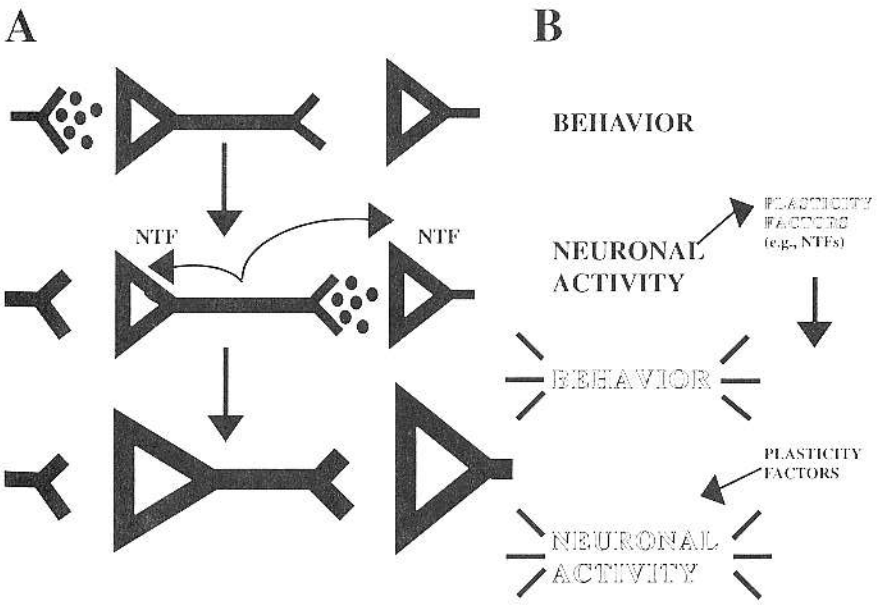


FIG. 4.1 Effects of growth factors: (A) Release of neurotrophic factors (NTFs) following neural stimulation, leading to enhanced neural growth and function; (B) Repetition of behavior leading to the release of additional plasticity factors and further strengthening of the neural pathways. From "Activity-Dependent Plasticity and The Aging Brain," by C. W. Cotman & S. Neeper, in *Handbook of the Biology of Aging* (4th Ed.) (p. 293) edited by E. L. Schneider and J. W. Rowe, 1996. Orlando, FL: Academic Press. Copyright by Academic Press, Inc. Reprinted with permission.

environmental support might well permit normal development of the experience-expectant type. However, *optimal* development may depend on experiences that are *not* typical of the species. Human cultures excel in inventing atypical experiences (Simon, 1969). Even within the range of human experience called "normal," there is tremendous variation in the type and degree of environmental enrichment; this variation, including experiences that are species-atypical, may produce important variation among people. High levels of talent development, for example, certainly depend on atypical experiences (Bloom, 1985).

Aside from unwarranted assumptions about the direction of causal control between mind and brain, brain research is often misconstrued when it is applied prematurely to educational problems. The aura of science surrounding brain research is attractive, and it is tempting to co-opt that glow for the realm of education. Unfortunately, scientific findings are often grossly overextended in the process. One notorious example involves the lateralization of brain function. Lateralization research has relied heavily on epileptic subjects whose corpus callosum, the major interhemispheric pathway, has been severed. Research on these subjects led to a fascinating discovery: The functions of the left and right hemispheres correspond, roughly, to linguistic versus spatial processing, and to analytical versus holistic processing (Reuter-Lorenz & Miller, 1998). But here, the application of science has run far ahead of the science itself. The tendency has been to spin off, prematurely, "theories" of learner types in which students are classified as right-brained or left-brained, and then to tailor instruction to accommodate those dubious distinctions. Other examples of the misapplication of neuroscience to education were documented by Bruer (1997). The tendency to misapply does not reduce the importance of neuroscience to an understanding of cognition, intelligence, and education. It is a reminder to be cautious, however, because in the past neuroscience research has been overextrapolated and distorted. Bruer (1997) appreciated that neuroscience *can* be bridged to education, but observed that the connecting bridge is usually made more sturdy if it is mediated by the interposed "island" of cognitive science.

THINKING DISPOSITIONS

Intelligent performance consists not only in the possession of important cognitive functions, but also in the propensity to use them. Tendencies to approach intellectual tasks in certain adaptive ways have been called *thinking dispositions*. They are, in essence, habits of mind that merge cognitive abilities with motivational and volitional tendencies. Conceptually, dispositions are similar to cognitive styles because they refer not to maximal capabilities, but instead to the optimal regulation of thought (Messick, 1994, 1996). Dispositions tend not to be recognized as readily as cognitive abilities, but have a quiet presence in all intellectual activity.

Some theorists have described global kinds of cognitive dispositions. Langer's (1997) construct of *mindfulness* represents a general awareness and critical engagement, and the ability to withhold an impulsive action or judgment (cf. Salomon & Globerson, 1987). Langer contrasted mindfulness with an endemic, uncritical mind*less*ness so often observed in everyday situations. Baron (1985) advanced a theory that explains lapses in rational thinking not as expressing an inability to think, but instead as reflecting insufficient *search*—that is, insufficient internal deliberation about the problem at hand. Baron argued that good thinking (or cognitive search) involves the generation of goals, possible actions to satisfy those goals (or ideas concerning what is possibly true), and evidence bearing on those possibilities. He presented evidence showing that, for most people and for much of the time, search is terminated prematurely.[5] The disposition to engage in cognitive search has a developmental aspect. As children mature, they tend to shift from a (prematurely) self-terminating strategy to one that is more nearly exhaustive. Of course, exhaustive search is not always warranted. Baron acknowledged it is possible to think *too* much about a problem—another kind of irrationality—but contended that human thinking is overwhelmingly biased toward *too little* search. Baron argued that if education were geared to develop the disposition to engage in more search, people would think and act more intelligently and find greater success in attaining valued goals, and so lead more satisfying lives.

A finer-grained theory of thinking dispositions was elaborated by Perkins, Jay, and Tishman (1993). Their taxonomy of dispositions includes: to clarify and seek understanding, to be planful and strategic, and to be intellectually careful. According to this theory, dispositions entail not only specific cognitive functions, such as the ability to seek clarity, but also conditions of use. Thus, the ability to *detect* fuzzy thinking should trigger the disposition to seek clarity. Paul (1993) advanced a functionally similar list of intellectual virtues, which includes a sense of justice, perseverance, integrity, humility, empathy, courage, confidence, and autonomy as these are expressed in the realm of thinking. It seems likely that such qualities of thought are facilitative not only on IQ test performance, but in making real-life decisions and taking actions that are "eco-logically" intelligent (Shore, 1996, p. 4). These descriptors imply that intelligence should be understood not just as the possession of certain knowledge or skill, but also as a more general pattern of intellectual life. It is perhaps in this sense that Anastasi (1986, p. 19) referred to intelligence as "a quality of behavior," and that Baron (1987) compared the teaching of intelligence to character education.

EMOTIONAL INTELLIGENCE

Theories of cognitive dispositions touch on a larger point: Many researchers now believe that to fully account for intelligent performance it is necessary to attend to emotional, motivational, and volitional aspects of thought. There is evidence, for example, that positive mood can enhance certain kinds of cognitive performance (Nantais & Schellenberg, 1999), and that anxiety can lead to performance decrements (Meichenbaum, 1972). It is therefore reasonable to view "broad-sense" intelligence as embracing emotional and motivational elements, rather than as a cool rationality devoid of feeling or desire (Snow, Corno, & Jackson, 1996; Sternberg, 1990b).[6]

Some writers have proposed that the ability to understand and control one's own emotional state is relevant to success and failure outcomes in many different contexts. The idea of a distinct *emotional intelligence*, entailing the ability to understand one's emotions and to use that information to guide thinking and action, was suggested as early as Thurstone (1924), formulated more precisely by Salovey and Mayer (1989-90), and popularized by Goleman (1995). It is easy to accept the importance of emotional controls in intelligent thought; of course, to say that these constitute an independent intelligence is a far stronger claim. Some commentators believe it is unwarranted. Eysenck (1998) maintained that the voluminous research literature on personality already addresses many of the claims associated with emotional intelligence. However, Mayer, Caruso, and Salovey (1999) presented evidence that emotional intelligence is factorially coherent and that it consists of definable competencies that develop with age and experience. On this basis, they argued that emotional intelligence meets the standards of a bona fide intelligence.

Questions about the legitimacy of emotional intelligence raises the larger question of how broad "broad-sense" intelligence should be. Most who have an opinion on the subject believe that intelligence has been conceptualized too narrowly in the past (Neisser, 1976). This does not mean that any adaptive behavior constitutes a separate and legitimate intelligence—yet, many speak and write as if that were true (e.g., note book titles touting the importance of "career intelligence," "competitive intelligence," and "sensual intelligence"!). Broadening what is meant by intelligence is a good idea, but an unbridled and fatuous proliferation of "intelligences" undermines whatever scientific gains have accrued over decades, and results in what Eysenck (1998, p. 109) called a "fundamental absurdity."

Research on emotional intelligence redresses an area of neglect. "Hot" cognitions, those involving emotions and intentions, have been paid short shrift in intelligence research. Perhaps the dismissal of emotion and related human characteristics as acausal epiphenomena stems from an intrinsic limitation of the

cognitivist metaphor, the digital computer. Bruner (1990), one of the early cognitivists, lamented the dehumanizing consequences of taking the computer metaphor too seriously:

> With the mind equated to [a computer] program, . . . there could be no place for "mind" in such a system—"mind" in the sense of intentional states like believing, desiring, intending, grasping a meaning. . . . How could a belief, desire, or attitude be the *cause* of anything in the physical world? . . . So action based on belief, desire, and moral commitment . . . is now regarded as something to be eschewed by right-minded cognitive scientists. (pp. 8-9)

To recognize the importance of dispositions, personality characteristics, motivational tendencies, cognitive styles, and so on, is to acknowledge that intelligent thought and action cannot be accounted for solely in terms of "cool" cognitions.

DISTRIBUTED INTELLIGENCE

Intelligent functioning is "not the solo dance of a naked brain" (Perkins, 1995, p. 323), but instead employs numerous physical, social, and symbolic supports. Increasingly, psychologists have appreciated the importance of social and technological supports to intelligent thought and action (Bower, 1995; Salomon, 1993). Inventions of culture can amplify intelligence. Thought and action occur in a world that is "thick with invented artifacts" (Pea, 1993, p. 48), which not only amplify intelligence, but also embody and express intelligence in their own right. Some artifacts indirectly constitute the cognitive operations of inventors on users (Pea, 1993). Every learner is engulfed in a cultural surround that channels intelligence, simultaneously abetting and constraining its expression.

Elements of the external world constitute distributed intelligence when they can be linked meaningfully to the cognitive system of the user, and the user becomes more capable as a result. Digital computers and communications devices, sensor-effector technologies, and miniaturization are salient examples of capability-boosting technologies (Hunt, 1995). A less flashy information technology, radio, also has qualities that shape cognition, and is likely to have played an important role in transforming some preindustrial cultures to ones that are information rich and technology dense. Some low-tech inventions have had even more profound cognitive consequences. The invention of written text, in particular, forever changed human cognition (Ong, 1982). In contrast to the spoken word, the written word provides a stability to language that permits dissection and extended critique. Because the reader and writer are often physically and temporally distant, the writer is forced to be explicit to a degree that is not necessary and perhaps even counterproductive in everyday discourse.

Just as the invention of writing amplified the effectiveness of cultural transmission exponentially, the printing press added further potency to the accumulation of knowledge over generations, and introduced massive changes in thought forms. Printed text supported a form of discourse that had no historical precedent, namely the form of expository prose that is in reality an extended argument, and that assumes rational exposition from beginning to end. Extended formal discourse was foundational to the development of modern science and democracy. According to Olson (1976), "The use of extended prose statements which are logically independent is a technique of relatively recent origin—a technique that was closely, though not exclusively tied to the invention of printing. . . . Knowledge was an extended logical essay—an assertion examined and re-examined to determine all of its implications in a single coherent text" (pp. 195, 197). The existence of the printing press meant that complex and extended arguments could be set down in relatively permanent form to be pored over, tested, critiqued, and debated by people removed from the author in space and time. Its effects did not stop there. Extended discourse also paved the way for its intramental analog, the elaborate and nuanced schema of the expert.

Newer electronic technologies may be producing similar effects. Electronic communication has forged high-speed and almost uninterrupted person-person and person-knowledge connectivity. Communication via the internet combines the interactivity of speech and the reflectivity associated with writing and print, and may have unprecedented effects in molding the cognition of subsequent generations (Warshauer, 1999). Also, the parallels between hypermedia webs and long-term memory are striking: Each contains an enormous corpus of information in multiple representational forms, which is content addressable through direct indexing (rather than serial access), fully cross-linked and, within domains, partially hierarchically organized. The line dividing mind and information technologies is blurring.

Intelligent performance is strongly associated with the availability of performance-amplifying technologies and the ability to use those technologies adeptly (Salomon, 1993). Although the technology-cognition alliance has always existed, its strength is growing. It is becoming clearer that thinking about intelligence as independent of the surrounding culture, and especially the "prosthetics" afforded by that culture, is a mistake. Societal changes occasioned by the advent of microcomputers are perhaps the clearest examples of the new fusion, but the braiding of human and machine capabilities promises to become much more intimate in the future. Information-processing devices are not only becoming smaller and more interconnected, they are also being fitted as "wearable" technologies, just as wristwatches made timepieces wearable decades ago. Intercommunication between wearable technologies can be accomplished by special fibers woven into clothes or by skin conduction. Prototypes of "heads-up" video displays on eyeglasses and a computer carried in a belt already exist (Pentland, 1998). Technologies are also going subdermal. The familiar cases of

pacemakers and cochlear implants are now being joined by such latecomers such as retinal implants and muscle actuators (Dunn, 1998). In one recent demonstration, researchers at Emory University developed a brain implant that permitted a paralyzed user to control a computer cursor simply by *thinking*. Technologies bridging humans and machines are often pursued with religious zeal (Noble, 1997). According to the president of Advanced Bionics, "We are going to make the blind see and the lame walk" (Dunn, 1998, p. 28). Such inventions are at once fascinating and frightening because in their logical extrapolation materializes the fantastic image of the man-machine cyborg.

Problems of social equity arise when there is unequal access to technologies that have qualities of cognitive amplification. Print, of course, has long divided societies into the literate and the nonliterate. Hunt (1995) declared that, in the age of information processing, "the aristocracy of this age will be the people who can solve new problems using the new technology" (p. 231). The new technologies are probably complicit in the bifurcation of society into the cognitive elite and all others. Paisley (1987) anticipated this when he noted: Future environments for applying literacy will provide extraordinary access to information, but only for those who understand the process of information seeking. They will provide extraordinary ability to generate and manage information. . . . In time, those who cannot apply literacy in such environments will not be regarded as literate" (p. 5). The segmentation of the world into the cognitive elite and those whose work will consist of routine performance will likely be determined, in part, by a person's access to and readiness to use amplifying technologies effectively.

EXPERTISE, GENIUS, AND CREATIVITY

Expertise and genius constitute highly valued end-states of effectiveness. The transition from novice to expert involves the expansion and extension of ability with a simultaneous contraction of domain focus. Expertise is, by definition, focused in particular domains, but this does not mean that there are no general characteristics of experts or similar paths followed in the development of expert knowledge and skill. Research has revealed such patterns in the cognitive and experiential history of experts across a wide range of creative expression. For example, expert performance requires an enormous body of domain knowledge (Larkin, McDermott, Simon, & Simon, 1980). Simon (1980) noted: "[One] thing that research on cognitive skills has taught us in recent years is that there is no such thing as expertness without knowledge—extensive and accessible knowledge" (p. 82). How much knowledge? Simon estimated that expertise in any field requires a mental fund of approximately 50,000 pieces of meaningful information (i.e., about 50,000 chunks) that can be quickly accessed and deployed. Building a knowledge base this size requires a huge investment of time. As Simon (1991) observed: "The level of a world-class expert is never achieved with less than 10

years of intensive, round-the-clock effort" (p. 36). To rise to the level of world-class performance in any field seems to require a sustained commitment over a period of at least a decade.

There are also strategic differences between novices and experts in how knowledge is organized and used. Novices rely much more on general problem solving processes, whereas experts tend to use domain-specific heuristics (Hunt, 1995). Expert knowledge is also more compactly organized into chunks or automated procedures that can be retrieved or activated with little burden to working memory. The resulting reduction in working memory load may permit higher-order strategic or creative cognition. Ochse (1990, p. 242; Jensen, 1992b) observed that the "employment of well-established routines frees attention from basic procedures to focus on the unusual or unique aspects of complex tasks."

Finally, there are regularities in the path toward expertise. In fields as diverse as chess, wrestling, figure skating, and musical performance, aspiring experts tend to adopt a regimen of disciplined study that Ericsson (1996) called *deliberate practice*. Deliberate practice consists of activities designed specifically to improve performance, activities that may or may not be intrinsically enjoyable (Ericsson, 1996; Starkes, Deakin, Allard, Hodges, & Hayes, 1996). In the evolution of the world-class performer, deliberate practice, sustained over years, is a better predictor of expertise than are hints of initial talent (Ericsson, Krampe, & Tesch-Römer, 1993; but see Winner, 1996). A deliberate practice regimen requires the capacity to focus one's interest and efforts, and to structure time daily. The regimen typically consists of about 3 or 4 hours of concentrated practice per day, broken into blocks of about 90 minutes, and engaged in habitually (Ericsson, Krampe, & Tesch-Römer, 1993). Over many years, the practice routine can build a huge base of knowledge and skills, but does so in a manner that avoids exhaustion.

Cumulative engagement in deliberate practice not only distinguishes between novice and expert status, but also between degrees of expertise (Ericsson, Krampe, & Tesch-Römer, 1993). Among elite violinists, for example, skill level is strongly predicted by the number of hours of deliberate practice accumulated over years. Displays of precocious talent are also identified with sustained and intense practice regimens (Bloom, 1985). Regularity and intensity of deliberate practice may ultimately be explained by motivational and self-regulatory abilities that sustain the drive to practice for hours each day, year after year (Ericsson, Krampe, & Tesch-Römer, 1993). The impressive association between accumulated deliberate practice and attained level of expertise seems to demystify elite performance, and calls into question commonsensical notion of native talent. According to Ericsson (1996), deliberate practice has so much explanatory power that it leaves "little room for the influences of innate fixed capacities" (p. 30). Even child prodigies, by some observations, display scant evidence of exceptional promise before the initiation of a serious practice regimen (Bloom, 1985; Ericsson, 1996). Indeed, the widespread adoption of Suzuki violin instruction can make thousands of normal Japanese children seem like musical prodigies (Winner, 1996).

However, the hypothesis of innate talent has not been completely discarded. Asserting the reality of innate talent, Winner (1996) found that child prodigies in artistic drawing displayed not only obsessional interest and engagement in picture drawing—what she termed a "rage to master"—but also produced superior drawings even at early stages of involvement.[7] Similar patterns have been detected in other pursuits, such as chess and guitar playing: Precocity seems to be linked to unusual interest and drive, but also, at least in some cases, to hints of talent that preexist the establishment of a practice regimen. If Winner is correct, then deliberate practice, although presenting a parsimonious explanation for the development of expertise, and one that is hopeful for education and human potential, does not furnish a complete account.[8] Other objections can be raised against the cumulative practice hypothesis. It is possible, for example, that people with high ability (i.e., more talent) find it sensible and rewarding to engage in intense, sustained practice, whereas those who lack talent recognize the fact and either give up serious pursuit or reduce their level of commitment (Sternberg, 1996a).

What about genius? For centuries, explanations for creative genius have mainly taken the form of myth and superstition (*genius* is partly derived from the Latin word for "tutelary spirit" or "genie"). The tendency to ascribe individual differences in intelligence to inborn and unchangeable factors is doubly strong when it comes to explaining great creative minds. There is general agreement that high IQ does not equate to genius, for genius is demonstrated only in its product, namely, a profound contribution to human culture (*genius* is also traceable to the Latin for "generate"; Simonton, 1984). Some children may therefore be properly called prodigies, but never geniuses. Likewise, intellectual daring may be a component of creativity, but authentic creativity goes much deeper and, like genius, is more defensibly moored to the criterion of a revolutionary cultural product (Mumford & Gustafson, 1988; Ochse, 1990).

Like expertise, the even more rarefied phenomenon of genius has been the subject of serious study and speculation. Simonton (1996), for example, attempted to demystify genius, just as Ericsson did expertise. According to Simonton, the chances of producing a great work are a direct function of the number of works generated. Creative masterpieces typically represent only a fraction of total output. This fraction is stable throughout a career and, surprisingly, roughly even across persons. By this model, eminence is achieved through a random "equal-odds" process, which in turn is a function of prolific output. As with expertise, studies of outstanding creative achievement reinforce the essential quality of relevant knowledge that is "profusely interconnected" (Simonton, 1996, p. 245).

Massive experience contributes to expertise, but expertise only makes genius possible, not inevitable. The eventual genius must *pass through* expertise—expertise must be attained and then transcended (Ericsson & Charness, 1994). In other words, to think "outside the box" requires knowing what's inside the box very, very well. In Polanyi's (1958, p. 195) terms, there must be a "dwelling in" before there is a "breaking out." Supreme acts of creativity are discontinuities

marked by the fusion and radical reorganization of existing knowledge (Kuhn, 1962; Mumford & Gustafson, 1988). At the highest level of creativity are those "transcendent products" that redefine a whole field (Briskman, cited in Mumford & Gustafson, 1988, p. 28).

CONCLUSION

The emergent theories surveyed in this chapter do much to expand the range of phenomena that are considered under the rubric of intelligence. These ideas can be interpreted according to the predictor-criterion models that have long dominated theories of intelligence. Psychometric theory postulates that tests sample from a larger hidden (or latent) ability or domain. This underlying ability is expressed not only on a test, but also in real-world criterial behavior that can also be sampled. One measure of a test's quality (i.e., its validity) is its ability to predict samples of criterial behavior. Emergent theories of intelligence enlarge on this basic model in two ways. First, the latent ability is not so hidden anymore. The black box has been opened and illuminated to reveal its unruly complexity and variegated nature. I have called the contents of this box the *intelligence repertoire*. The second contribution of emergent theories is that they enlarge and differentiate both intelligence (the predictor) and what it predicts (the criterion). On the criterion side, we can ask what kinds of thought and behavior truly manifest intelligence. Diverse performance realms might draw from differing facilitative functions. Criteria for success in different ecologies might overlap substantially, minimally, or not at all with the standard interpretation of intelligence. Once the criteria of effectiveness are understood more exactly, that understanding would result in a parallel appreciation for new and broader aspects of the intelligence repertoire, such as those described in this chapter. Thus, the expression of intelligence and the underlying proficiencies that permit intelligence at once become broader *and* more exact than in the original psychometric conceptualization. One implication is that the improved model can be used to enhance the underlying ability. That is, the predictor-criterion relation need not stop at prediction, but can advance to the higher level of *preparation* (Snow, 1996), which is to say *education* in its broader and truer sense.

NOTES

1. Sloboda, Hermelin, and O'Connor (1985) studied one musical savant, NP, an autistic man in his early 20s. In comparison to a professional musician of normal intelligence and comparable age, NP was much more adept at reproducing on the piano Grieg's Op. 47 no 3 ("Melodic"), and could play it almost flawlessly 12 minutes after first exposure. The error rate for the professional musician, by contrast, was 10 times that of NP. However, when both subjects were exposed to a more unusual (although simpler) atonal composition, Bartok's "Whole tone scale" from Book 5 of *Mikrokosmos*, NP's attempts to reproduce the piece declined radically, whereas the professional musician was able to master the composition after three trials. In reproducing Bartok, NP's errors were "structure preserving," meaning that they tended to impose more conventional melodic structure onto the composition, suggesting that NP's "expertise [could] not survive outside [the] framework" of more conventional tonal structures (Sloboda, Hermelin, & O'Connor, 1985, p. 165). One possible interpretation of the savant's inflexibility is that high competence is developed in memory codes that are closer to perception, but that more abstract meaning-based representations are poorly developed (Anderson, 1983). This, in turn, would imply a more unified interpretation of mind.

2. Messick (1992) saw the possibility of convergence between MI theory and psychometric models of intelligence, and proposed that the multiple intelligences model could be accommodated within a hierarchical structure with little or no loss of its implications for education. In such an arrangement, the hierarchy would consist of "semi-autonomous ability complexes or modules, cross-connected by higher-order general processes" (p. 374). These abilities could be used to draw individual profiles of students' strengths and weaknesses, and even to redress the narrowness of school curricula that leads to the neglect of certain abilities and the overemphasis of others.

3. Project START investigators also tested the effectiveness of instruction based (somewhat loosely) on MI theory. Primary grade students from 16 elementary schools were divided into two treatment groups (MI instruction plus mentoring, MI instruction with no mentoring, total N = 256 students) and a control group (N = 86). Teachers of students in the treatment groups were trained to enrich and broaden instruction "via multiple intelligences" by, for example, developing and using "multiple activities for a single task goal" (Callahan et al., 1995, p. 71). The investigators found that "the intervention had no significant effect on the achievement on the treatment groups in any of the grades" (pp. 92-93). Although Project START may cast some doubt on the utility of general enrichment inspired by MI theory, it does not constitute a strong test of MI theory's applicability to education because it did not systematically match students' MI profile with instructional treatments (however, cf. Cronbach & Snow, 1977, for negative results obtained in similar interventions).

4. As an example, consider the analogy (Sternberg, 1985a), Lawyer : Client :: Doctor : ____. A solution of the analogy can be explained in terms of four components: *encoding*—each of the three terms of the analogy is entered into short-term memory, and each term is read and recognized; *inference*—the relationship between the first two elements, *lawyer* and *client*, is determined; *mapping*—the relationship between the first and third elements, *lawyer* and *doctor*, is determined; and *application*—the relationship between the first two elements is then applied to the third term to generate the ideal fourth term, completing the analogy. In order to explain composite item and test performance, each of the constituent components becomes an individual difference variable. In componential analysis, Sternberg's dependent variable of choice has been response time, which is the time needed by subjects to complete the analogy correctly. To obtain response times for individual components, Sternberg manipulated the analogies: Sometimes all of the analogy was given at once; at other times, part of the analogy was "precued" and the timed phase included encoding the new part of the analogy plus the response. By subtracting response times for partial sets from the response time for a complete analogy, Sternberg was able to estimate a response time for each item component. He then related the response times for components back to psychometric measures, such as aggregate performance on analogies, or to other cognitive abilities or measures of intelligence.

5. The premature termination of search is illustrated in Sternberg's (1977) componential analysis of analogy items. Errors in solving analogy problems were largely accounted for by "premature self-termination of information processing" (Sternberg & Gardner, 1982, p. 249).

6. "Broad-sense" intelligence has previously been proposed to include social intelligence. The notion that skilled social cognition constitutes one expression of intelligence can be traced to E. L. Thorndike in the early 20th century, and is an explicit element in Guilford's (1967) and Gardner's (1983) theories. Despite the intuitive rightness of the idea that people differ dependably in social cognition, and that these differences have important real-world consequences, there has been a great deal of difficulty establishing social intelligence as a legitimate form of intelligence that is distinct from an analytic intelligence (Salovey & Mayer, 1989-90).