

disadvantaged families, so that the orphanages could become a repository for those children for whom society does not have a place. Prisons have already been built to warehouse adults for whom we cannot find another place. The death penalty is again legal in many states, and studies have shown that this final solution is more likely to be invoked when a criminal is a member of a minority group. Efforts to liberalize laws that allow compassionate death or "assisted suicide" are seen as contributing to the dignity of death, but these laws must be evaluated in a eugenic context. When people speak of relieving the burden of suffering of the sick, one must ask whose burden is actually being lifted? Is it that of the individual, or his family, or health care workers, or society at large? Any answer other than "the individual" potentially comes from tainted motives, and begins to sound suspiciously like a eugenics program in action.

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The Nature of Nurture Defining Environmental Influences

The old dichotomy of nature or nurture, first made by Galton more than a century ago, has been used so far without exploring it more deeply. But this dichotomy is misleading for several reasons, and it is now time for clarification. Most scientists believe that the dichotomy itself is incorrect, and that virtually every trait is mediated by both nature and nurture, working somehow in concert. Furthermore, it is quite outdated to speak of "nature or nurture" when we know that nature, as it was meant by Galton, is equivalent to genes in modern parlance. As has already been discussed; a gene is simply that part of the DNA molecule that specifies the construction of a particular protein. Environment, as Galton used it and as it has been used since, is something of a catchall; everything that is not genetic is, by definition, environmental. But this is intellectually unsatisfying; we must somehow be more explicit about the environmental influences that affect expression of a trait. Or, to put it another way, what is the nature of nurture?

Environmental Influences Broadly Defined

Nurture is often taken to mean the social environment that surrounds and protects the child from birth to independence. This would include early interactions with parents and siblings, as well as the more sporadic interactions with whatever members of the extended family happen to be around. Somewhat

later the environment expands to include teachers and friends, and these parts of the social environment assume greater and greater importance with the passing years. Finally, those persons with whom an adolescent or young adult has lasting friendships or love relationships play an increasingly important role, whether those persons are of the same or of the opposite sex.

But considering environmental influences to be synonymous with social influences is really very narrow and restrictive. Instead, environmental influences should be broadly defined as anything and everything not explicitly in the genes. This opens the door to many factors that might otherwise be overlooked or undervalued, including factors in the physical environment. And it also opens the door to complex interactions between genes and the environment that are neither entirely genetic nor entirely environmental. While most of these influences on behavior are still speculative, the idea that the environment has a complex and subtle impact on the individual is really not at all speculative.

In fact, the environment can have a profound effect on the individual before the individual is even born. Environmental toxins or drugs can pass through the mother's body, to impact directly on the unborn child in many ways. An example of this is the drug thalidomide, which was taken by pregnant women 40 years ago to control morning sickness, but which had a devastating effect on fetal development. Alcohol as well can have a profound effect on the fetus, and fetal alcohol syndrome is known to be associated with mild mental retardation. The hormonal environment that the child encounters *in utero* is also potentially important, and maternal hormones may be able to modulate or alter the effect of the fetal genome. In addition, the nutritional status of the mother can have a profound impact on the development of the fetus, and developmental patterns established early in fetal life may take an entire lifetime to work out.

After birth, the newborn infant is extremely vulnerable to vagaries of the environment, and the physical needs of the newborn must be met in order to ensure survival. The nutritional

history of the mother can be important if the mother is nursing, and the early nutritional history of the baby itself is obviously critical. But feeding and freedom from physical harm or abuse is not enough; the infant must be loved, touched, cleaned, kept warm and free of disease, and given adequate stimulation and rest. Only when all of these physical conditions are satisfactorily met can the child begin to fulfill its genetic potential. Since mere survival can occur under conditions that are far from optimal for growth and development, this implies that the environment will often hinder a child from fulfilling its genetic potential. This is why it is so critical that care be provided by someone sensitive to the needs of the child.

Direct interactions between the infant and the mother immediately after birth are extremely important, and the relationship with the mother remains important for the entire life of the child. The personality of the child and that of the mother can interact in a very important way to give this relationship a structure that may last a lifetime. Many neonatal behaviors seem designed to elicit warmth and nurturance from the mother. But if a child is somehow deficient in giving these signals, or if the mother is deficient in receiving these signals, this deficiency can have a major impact on the child. The ability to elicit or give nurturance may in fact be hereditary, so that the same thing that interferes with a child's ability to elicit nurturance may interfere with the mother's ability to give it. In fact, it is likely that the hereditary component of a social behavior such as warmth or empathy is first expressed in interactions with the maternal "environment."

While it is clear that maternal acceptance and nurturance of the infant is critical, the optimal development of a child may also require a father figure or an extended family. It is quite reasonable to suppose that infants are directly or indirectly sensitive to the social supports surrounding their mother. Rearing an infant can be extremely stressful, involving many sleepless nights, many disruptions of prior routine, and many new anxieties, and the new mother often has little time or energy to deal with her

own feelings. The importance of an effective social support network around the mother at this time cannot be overestimated. It is quite likely that infants are sensitive to this support network in some way or another, since maternal anxiety can be transmitted to the infant by many different cues. In fact, maternal stress can even reduce milk output, so that a nursing mother who is overstressed may be unable to meet the nutritional needs of her child.

The family unit forms a sort of collective environment that can be rich and supportive, or full of tension and dissension. Very little is known about the sensitivity of the newborn to family cues, but it is clear that even very young children are exceedingly sensitive to the nuances of family life. Family discord may lead directly to parental neglect, or it may cause the child to suffer indirectly, since an emotionally drained mother may be unable to provide adequate care for her child. If there is family discord, children may be drawn into it as a part of the power struggle between parents, or children may be excluded or marginalized, as neither parent may have the energy to meet the demands of their children. In either case, family discord can potentially have very damaging consequences for the children.

The larger social context around the family is a moderating influence that can be either benign or malignant, but is only rarely beneficial to a child. The social context can seldom compensate for an inadequate family life, but it can easily destroy the best efforts of a family to support and protect a child. Children born to the terror of the Warsaw ghetto or the Russian pogroms or the civil war in Bosnia may never reach their full potential because of the awful circumstances of their birth. On the other hand, there is evidence that children who are in a larger social context that is highly supportive, such as a kibbutz in Israel or a Head Start Program in Harlem, may derive little lasting benefit if their family life is already adequate. But, as young children grow into young adults, the larger social context becomes increasingly important. Teachers and friends assume an ever-larger role in the child's life, so that parents often begin to

feel extraneous as a child reaches adolescence. The parental feeling of being extraneous is almost certainly inaccurate; parents remain important in the lives of their children even as these children reach adulthood. Nevertheless, it is almost completely unknown how and to what extent the family environment and the social context interact in fostering the maturation of a child, and how this interaction changes as the child ages.

In addition to these direct effects of the environment on the child, there can be a very complex interplay between genes and the environment. How a parent chooses to bring up a child forms the environment of that child, but it arises in part from the genome of the parent. Most parents provide their children with both genes and a home environment, and the two interact and reinforce each other in subtle ways. The interaction can be passive, such as when children receive both "smart genes" and an enriched environment from their parents. But there can also be an active interaction between genes and the environment; a child with a particular behavior can evoke something from the environment that actually reinforces the behavior. For example, children with high verbal ability are more likely to spend time reading, thereby further enriching their verbal ability. Or children who are more intelligent are more likely to test their environment continually, and to elicit more interesting responses from the people and things around them. Alternatively, children who are inherently somewhat hostile are more likely to evoke hostility from the people around them, so that hostility too can become self-reinforcing. And the interplay between genes and environment can take a lifetime to resolve; antisocial boys are more likely to experience social rejection as adults and have a higher than normal rate of divorce, unemployment, and criminal behavior.

How a child structures his own environment is critically important, and may radically affect how different children experience the same social context or even the same family. We are not passive participants in our own lives; we actively structure the environment around us all the time, and children are

certainly capable of this as well. The structure a child chooses to impose on his environment is the structure with which that child feels most comfortable, and this structure is likely to have something of a genetic component.

Lead Exposure as a Paradigm for Environmental Influence

It is easy enough to claim that the environment can limit the success of a child in attaining its genetic potential, but what is the evidence for this claim? Is there any reason to think that the environment can actually constrain the expression of a child's full capacity? The easy (and politically correct) answer, of course, is "Yes," but the evidence is rather more fragmentary than one might expect. Perhaps the clearest example of an environmental effect on the expression of a genetic trait is seen with lead, a common environmental pollutant that can have a profound effect on human intelligence.

People have known for more than a century that lead is toxic at high concentrations; in fact, the Mad Hatter in *Alice in Wonderland* was supposedly driven mad by lead exposure suffered during the process of making hats. But it is only relatively recently that scientists discovered that lead, at levels often found in the environment, can also reduce IQ and can lower classroom performance. This conclusion is the result of studying more than 3000 children from Massachusetts, who were examined to determine the normal range of lead exposure, and the consequences of lead exposure at the upper bounds of the normal range.¹⁹ A very clever research strategy was used for this; first- and second-graders were asked to give their shed baby teeth to their teacher, who then inspected each child to verify that there was a corresponding empty tooth socket. Shed teeth were chemically analyzed for lead content, with the idea that teeth are a stable and long-term record of lead exposure, whereas blood samples are likely to record transient or recent lead exposures. After the normal range of lead exposure was determined, children in the

top 10% of tooth lead content were identified, and these children were compared to children in the bottom 10% of tooth lead content. Each child was tested for IQ and their academic performance and classroom behavior were rated by their teacher. In addition, scientists tried to measure every other feature of the environment that might conceivably affect IQ or interfere with school performance. High lead exposure was associated with reduced IQ, and specifically with reduced verbal ability and reduced ability to concentrate for long periods of time. Lead-exposed children were more likely to have behavioral problems at school, and high lead exposure was associated with distractibility, impulsiveness, an inability to follow directions, hyperactivity, and poor overall cognitive function.

Over the years, this pioneering study has been confirmed by many other scientists who have been able to fill in some rather striking details. Lead exposure is more common among the poor, who often live in older buildings that have been painted in the past with lead-based paint. Since these buildings are less likely than normal to be well-maintained, or to have received a recent coat of paint, many inner-city homes are heavily contaminated with lead in the form of chips or dust. Contaminated soil is also a significant source of lead exposure in the inner city, presumably as a result of fumes from leaded gasoline. Children with high lead exposure are more likely to have a history of pica, a medical condition in which children eat inappropriate things such as paint chips or soil, which could, of course, account for their high lead exposure. Low-level lead exposure at birth is associated with reduced IQ at age 7, although environmental cleanup is associated with an increase in IQ among children who are moderately lead-poisoned. While current therapy to remove lead from the bloodstream seems to be relatively ineffective, time is an ally; environmental remediation can produce a long-term improvement in both blood lead levels and IQ. An increase in blood lead levels, from roughly the lowest third of normal to the highest 10% of normal, is associated with a reduction in IQ of about five IQ points.²⁰ Five IQ points may not seem like much, but millions of children are exposed to high levels of lead every

year; this is perhaps tantamount to reducing the IQ of the entire country by a few IQ points on average.

While this research has been somewhat controversial, there is nevertheless very clear evidence that lead can reduce IQ and impair classroom performance. Since lead exposure has a grossly disproportionate impact on poor and minority children, lead poisoning may be responsible for some of the IQ discrepancies that have been reported in the past. Lead poisoning is thus a clear example of how an environmental effect may masquerade as a genetic effect. It is also an example of the often malignant effect of the environment on the individual; to envision an environment that has only positive effects on behavior is thus truly misguided. Toxic effects of the physical environment on the individual are legion, as mercury and several other heavy metals are also known to reduce IQ. But the truly frightening possibility is that many, perhaps even most, environmental effects on behavior have not yet been identified.

The Importance of the Social Environment

The environment is composed of both physical and social components, and we have seen that a toxic physical environment can limit the attainment of a child's full genetic potential. But it is much less clear whether or not a toxic social environment can also limit the attainment of human potential. Examples can be found in which profound social deprivation has a devastating effect on human development, but it is very difficult to determine whether moderate social deprivation is harmful. Similarly, it is virtually impossible to determine whether deliberate social enrichment is beneficial to the developing child. It often seems that everyone has simply assumed that social enrichment is beneficial, since profound social deprivation is clearly harmful.

There are several very colorful, perhaps apocryphal, stories of "wild children" who suffered the grim consequences of social deprivation. One of the earliest such stories, published in 1807, was of the "wild boy of Aveyron" who was captured in the

forests of France at the age of about 12.¹ When captured, he could not speak or walk—he only shrieked and grunted, and crawled on all fours—and was totally indifferent to other humans. The boy was believed to have become retarded because of social isolation, so a kindly physician sought to educate him in human ways. After years of effort, the boy was able to discriminate among objects by sight or touch, to deal with simple abstract concepts, to write a few words, to respond positively to affection, and to respond to his new name "Victor." Although Victor was never able to achieve an intellectual level normal for his age, he did make great strides, and his achievements provided evidence for those who believed that mental development depends on a favorable social environment.

In 1942, J. A. L. Singh claimed in his book *Wolfchildren and Feral Man* that he had found two "wolf children" in India. Singh had been a missionary in 1920, when he heard tales of a "man-ghost" living in a nearby jungle. On inquiring about this apparition, he was taken to an abandoned termite mound, which was being used as a den by wolves. Singh had a hunters' blind set up near the den, and after several days he observed two female wolves with two wolf cubs and two human children, the latter completely covered with dirt and virtually unrecognizable. Several days later the children were caught, and both were found to be girls; one less than 2 and one about 8 years old. The younger child, named Amala by her captors, died within a year of being caught without ever showing significant human capabilities. The older child, named Kamala, lived for nearly 9 years in a missionary orphanage, and was able to undergo a partial transformation into a more human child. Initially, Kamala ran on all fours, lapped her food from a bowl, showed a preference for raw meat, and seemed more interested in farm animals than humans. She could not talk, but frequently howled like a wolf at night, and she was reported to be more vicious than a wolf cub. But Kamala gradually learned to walk, to use her hands, and to eat cooked food, and she also learned to show affection to some people. Eventually she learned a vocabulary of about 30 words before she died of a chronic illness. Her case suggests that an

adequate social environment is required for proper development in childhood.

One of the strangest stories ever told about the consequences of social deprivation involves a young man named Kasper Hauser, who mysteriously appeared at the Nuremberg city gates in Germany in 1828. He was barely clothed, nearly mute, mentally confused, and strangely uncoordinated, although he seemed to have walked for many miles. No one could identify him, and he was unable to tell police anything about himself. He astonished the city fathers by trying to pick the flame off a candle, and further investigation showed that his mental faculties seemed to be intact but almost undeveloped. Over time, Hauser learned to speak and to write, and he eventually told authorities he had been raised in total darkness in a cellar, had been fed only black bread and water, and had never had human contact other than for a few moments each day when a man brought him food. His true identity was never discovered before he was apparently murdered 6 years later. As strange and perhaps apocryphal as this case is, it suggests the importance of the environment in fostering the development of a child.

There is also clear evidence that environmental deprivation in adulthood can be damaging. The Russians are alleged to have developed tortures based on sensory deprivation, using the principle that the absence of environmental stimuli causes sufficient mental anguish that physical pain is almost irrelevant. There is also evidence, from closer to home, that sensory deprivation can cause great mental distress. The solitary confinement or "boxcar" cells at the federal maximum security prison in Marion, Illinois, which are used for the most incorrigibly violent of prisoners, are small steel cubicles without natural light. The cells are insulated so that sound cannot get in or out, the ventilation is poor, and the only light is provided by a single 60-watt bulb. A prisoner who becomes ill has no way of alerting his captors, because the cells are so isolated from the rest of the prison. In fact, these cells are believed to be driving inmates insane, and several court cases have involved litigants who

believe that incarceration in these cells constitutes cruel and unusual punishment.⁷

There is no doubt that an environment that falls within a normal and expected range of variation is important for development. As human beings, we are adapted at birth to respond to a certain range of possible environments, and as long as our environment falls within that range, the specific form of the environment may not matter very much.²¹ Children are generally well-attuned to their environment, yet unaware of other possible environments, so that they cannot objectively assess the quality of their own environment; because of this, many children of poverty do not fully realize they were poor until they are older. In the absence of books and toys, family social interactions may become more important, so that environmental "complexity" is enhanced in other ways. Close proximity of neighbors in the inner-city may provide a rich stew of experiences that a child growing up in suburbia would never experience. While a city child may not often experience the quiet joys of a pastoral setting, he will experience a barrage of sights and sounds that would be unimaginable in the country. If a satisfying degree of environmental richness and complexity is available, it may not matter at all what particular form of stimuli are present. In other words, many different environments may be functionally equivalent to one another, as long as they fall within an expected range of variation. However, if an environment falls outside the normally acceptable range of variation, it might fail to promote proper growth and development of the child. This implies, of course, that many environments may be neutral, in terms of their effect on child development, while some few environments are actually detrimental.

Children are apparently able to structure their own environment, by picking and choosing among available stimuli.²¹ Given a sufficiently varied environment, children are able to sort themselves into a personally satisfying milieu, according to their interests, their talents, and their personality. There is evidence that a child selects a particular environment because of heritable

features of their personality, which implies that genes and environment are constantly interacting. The freedom to manipulate the environment increases with age, so there is an increasing ability to tailor the environment to fit the genes. The interaction between genes and environment continues for one's entire lifetime, and is likely to color career choice as well as choice of spouse and recreation. For example, few people would feel comfortable working in the maelstrom on the floor of the New York Stock Exchange, just as few people would enjoy working in isolation in a monastery. Many people might be uncomfortable in a confrontational occupation such as trial law, but many people would be equally uncomfortable in an occupation that permitted them no social contact. Similarly, few outgoing people would be interested in a relationship with an introverted, non-social person, just as few shy persons would enjoy a relationship with a highly extroverted "party animal." Each evening, most people have a choice of what leisure-time activity to engage in; the fact that some will elect to read, while others are watching television, using a Stair Master, or sleeping, is a result of genetics as well as environment. We are constantly presented with choices and the choices we make help to formulate our environment, so that every person experiences an environment that is based, at least in part, on their genes. All life experiences span a broad range, and the balance point we choose within that range may reveal much about our genes.

This idea has several rather startling implications. First, if most childhood environments are functionally equivalent, then efforts to enrich the environment may not be very productive. This further implies that while all parents may not be great parents, most are good enough. Ordinary parents are likely to have roughly the same impact on their children as those parents recognized as "superparents." Thus, beyond the contribution of "good genes," the parental role in creating "superchildren" is minimal; reading to an infant *in utero*, or playing Beethoven at the cribside, or trying to teach a child chess at age 5 is unlikely to have a lasting effect on development. This is a refreshing

turnabout from the belief that parents have the power to ruin their children in so many ways. As Sandra Scarr, past president of the Society for Research in Child Development, says, "fortunately, evolution has not left development of the human species . . . at the easy mercy of variations in the environment. We are robust and able to adapt to wide-ranging circumstances. . . . If we were so vulnerable as to be led off the normal developmental track by slight variations in our parenting, we should not long have survived [as a species]."²¹

Another implication of the idea that children structure their own environment is that it may always be difficult to intervene successfully in the development of a particular child. In fact, if children actually do structure their own environment, they could actively resist a structure being imposed on them. Furthermore, intervention into a child's environment might not produce a positive result if his environment is already adequate; intervention could only help if the child's environment falls outside the range of "adequate." In other words, perfect nutrition will not make everyone an athlete, nor will a perfect school system make everyone an academic. The problem is that while it is reassuring to think that most environments are adequate, it is not known what actually constitutes "adequate." It may be that an adequate environment is common, or it may be that many environments are less than adequate; as of yet, there is no way to determine the adequacy of a particular environment.

In the 1960s, scientists studied adults who were tested as below average in infancy and preschool, but who had then received supplementary educational opportunities. They found that these people benefited greatly from the educational intervention, in terms of better grades in public school. This led scientists to conclude that a rich and varied environment is important for childhood development, and that the richer and more varied, the better. This was a major impetus for Project Head Start, an effort to enhance scholastic achievement of inner-city and minority children. Although the outcome of Head Start is generally assumed to be positive, several recent efforts to

demonstrate this positive benefit have failed. In fact, it is not really known whether Head Start has been successful in the long term, or whether the degree of success has warranted the effort and expense. Nevertheless, programs like Head Start should not be abandoned, because it is possible that some children served by the program are suffering an otherwise inadequate environment, and these children might greatly benefit from the new opportunities. But we should not necessarily expect Project Head Start to increase the long-term scholastic attainment of all of its participants by a great deal.

New Tools for an Old Problem

Human behavior is the most complex and difficult problem ever attacked by geneticists, and it is likely to resist their best efforts for a full explanation for many years to come. In fact, it is quite likely that classical genetics would never be able to solve the most puzzling problems in behavioral genetics. This difficulty in understanding human behavior arises for several reasons. The first major problem for the behavioral geneticist is that human behavior is far more complicated than the simple physical traits that Mendel was able to study in his pea plants. When Mendel did his breeding experiments he could look at a pea seed and easily determine whether that seed was smooth or wrinkly, but human behavioral options cannot be so easily dichotomized. The second major problem is that, unlike most of the research for which classical genetics is best suited, human behavior does not involve one or a few genes. Instead, human behavior is determined by a large number of genes, each of which probably has a small effect, and there may even be many different combinations of genes that result in the same behavior. The last major problem for the behavioral geneticist is that the environment can have a profound effect on behavior, so that a genetic effect can be either accentuated or blunted by the environment.²²

Given all of these major problems, it is a good thing that modern behavioral geneticists have at their disposal a range of new tools that could scarcely have been imagined even a decade ago. These new tools of molecular genetics will be described here, from the standpoint of both their strengths and their