Patrick Bateson

The origins of human differences

With increasing frequency the media report the discovery of genes *for* distinct human characteristics, such as athletic prowess or male promiscuity. Yet it is obvious that experience, education, and culture make a big difference in how people behave, whatever their genetic inheritance. Why is it that behavioral and psychological development are so often explained in terms of the exclusive importance of one set of factors, either genetic or environmental?

Oversimplified opinions may derive from a style of advocacy that is common in many academic debates. If Dr. Jones has overstated her case, then Professor Smith feels bound to redress the balance by overstating the counterargument. The way scientists analyze complex processes further amplifies the confusion. When somebody has conducted a clever experiment demonstrating an important long-term influence on behavior, that person has good reason to feel pleased. It is easy to forget, however, about all those other influences that a competent scientist contrives to keep constant or to play no systematic role.

Even if the debates are seen for what they are – irritating examples of advocacy – is it not the case that complex human behaviors have come from somewhere? In some instances, surely, they will be inborn and in other instances they will be acquired by experience. But the apparent good sense of this view leaves out of account the ways in which the inborn can be changed by experience and the ways in which the gathering of experience is itself inborn. Even so, it is worth looking at some straightforward examples.

Studies of animal behavior do, indeed, tell us that much complex behavior can develop without opportunities for practice. The European garden warblers that have been hand-reared in cages nevertheless become restless and attempt to fly south in the autumn, the time when their wild counterparts migrate in that direction. The warblers continue to be restless in their cages for about a couple of months, the time it would take them to fly from Europe to their species' wintering grounds in Africa. A similar restlessness during the following spring sim-

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ulates their return flight north. This migratory response occurs despite the birds' rearing in social isolation, with no opportunities to learn when to fly, where to fly, or for how long. Cases like these are marvels of developmental biology. They involve the construction of a nervous system that can express the full complexity of the behavior. But the principles involved are no more difficult to understand than those involved in the construction of, say, a kidney.

Continuing with this general line of argument, many aspects of human behavioral development recur in everybody's life despite the shifting sands of cultural change and the unique contingencies of any one person's life. Individual differences among humans seem small when any human is compared with any chimpanzee. All humans have the capacity to acquire language, and the vast majority do. With few exceptions, humans pass the same developmental milestones as they grow up. Most children have started to walk by about eighteen months after birth, have started to talk by two years, and have reached sexual maturity by their late teens.

Similarly, human facial expressions have characteristics that are widely distributed across cultures. The emotions of disgust, fear, anger, and pleasure can be easily deciphered in facial expressions in any part of the world. Toward the end of his life, Charles Darwin wrote *The Expression of the Emotions in Man and Animals*, a book that provided the stimulus for observational studies of animal and human behavior that have continued into modern times. Darwin would show his friends and colleagues pictures of people expressing various emotions and ask them, without further prompting, to describe the emotions. In one case he showed a picture of an old man with raised eyebrows and an open mouth to twenty-four people, only one of whom did not understand what emotion that expression indicated. Such research as well as his extensive correspondence with travellers and missionaries convinced Darwin that humans from all round the globe express the same emotion in the same way. Darwin concluded: "That the chief expressive actions, exhibited by man and by the lower animals, are now innate or inherited – that is, have not been learnt by the individual, – is admitted by every one."

Subsequently, an enormous photographic archive of human expressions from different cultures at different stages of economic development was formed. The similarities in the appearance of the smile or the raised eyebrows, for example, are striking. The cross-cultural agreement in the interpretation of complex facial expressions is also remarkable. People agree not only about which emotions are being expressed, but also about which expression of a particular emotion is the more intense.

All of this might seem straightforward; the argument that some human behavior is instinctive seems to be correct. However, the concept of instinct is riddled with confusion. For some, it means a distinctly organized system of behavioral patterns, such as those involved in searching for and consuming food. For others, 'instinct' simply refers to behavior that is not learned, that is present at birth (the strict meaning of 'innate'), or that emerges at a particular stage in the life cycle. Another suggestion is that 'instinct' refers to behavior that, once developed, does not change, or to behavior that develops before it serves any biological function, like some aspects of sexuality. At the same time, some define 'instinct' as those behavioral patterns shared by all members of the species (or at least by members of the same sex and age), while others define it as the behavioral difference between individuals caused by a genetic difference. None of this would matter if it were always the case that all examples of supposed instinct had all the characteristics variously attributed to it. That, unfortunately, is not the case; many examples have some of the characteristics but not others.

One aspect of the unitary concept of instinct that has unravelled on further inspection is the belief that learning does not influence instincts once they have developed. Learning modifies many cases of apparently unlearned behavioral patterns after they have been used for the first time. Human babies who have been born blind, and consequently never see a human face, nevertheless start to smile at around five weeks – the same age as sighted babies. But while sighted children learn to modify their smiles according to their experience, producing subtly different smiles that are characteristic of their particular culture, blind children become less responsive and less varied in their facial expressions. Experience can and does modify what started out as apparently unlearned behavior.

Conversely, some learned behavioral patterns are developmentally stable and virtually immune to subsequent modification. The songs some birds learn early in life may be extremely resistant to change once they have been acquired. Similarly, modes in humans of perceiving language and articulating particular sounds, once acquired, are extremely difficult to change in adulthood.

The idea that one meaning of instinct, 'unlearned,' is synonymous with another, namely, 'adapted through evolution,' also fails to stand up to scrutiny. The development of a behavioral pattern that has been adapted for a particular biological function during the course of a species' evolutionary history may nonetheless involve learning during the individual's life span. For example, the strong social attachment that young birds and mammals form to their mothers is clearly adaptive and has presumably developed through evolution. And yet the attachment process requires the young animal to learn the distinguishing features of its mother. An important point is that Darwinian selection, by acting on mechanisms that regulate changes in behavior in response to challenges from the environment, can increase plasticity and behavioral diversity.

In short, many behavioral patterns have some, but not all, of the defining characteristics of instinct, and the unitary concept breaks down under closer scrutiny. The various theoretical connotations of instinct – namely, that it is unlearned, caused by a genetic difference, adapted over the course of evolution, unchanged throughout the life span, shared by all members of a species, and so on – are not merely different ways of describing the same thing. Even if a behavioral pattern is found to have one diagnostic feature of instinct, it is certainly not safe to assume that it will have all the other features as well. Perhaps for that reason Darwin wisely refused to define 'instinct.' In *The Origin of Species* he wrote:

> An action, which we ourselves require experience to enable us to perform, when performed by an animal, more especially by a very young one, without experience, and when performed by many individuals in the same way, without their knowing for what purpose it is performed, is usually said to be instinctive. But I could show that none of these characters are universal. A little dose of judgment or reason . . . often comes into play, even with animals low in the scale of nature.

Should we be worried about the confusion with how terms are used? Only if we suppose that we can easily divide behavior into the two categories 'innate' and 'learnt.'

One of the triumphs of behavioral biology in the latter part of the twentieth century was to relate differences in mating systems, parental behavior, foraging, and many other aspects of adult behavior to differences in ecology. A comparable coherence can be brought to the great variation in the ways in which adult behavior can develop. In particular, the role of experience is likely to vary considerably from one behavioral system to another. In predatory species, the successful capturing of fast-moving prey requires considerable learning and practice. The osprey does not learn to snatch trout from water overnight. Such animals that rely upon highly sophisticated predatory skills suffer high mortality rates among their young, and those that survive are often unable to breed for years. This is because they have to acquire and hone their skills before they can capture enough prey to feed offspring in addition to themselves. In such cases, a combination of different developmental processes generates the highly tuned skills seen in the adult.

The developmental processes that make learning, like behavioral imprinting, easier at the beginning of a sensitive period are timed to correspond with changes that the individual will encounter as it develops under natural conditions. The processes that bring the sensitive period to an end are often related to the gathering of crucial information, such as the physical appearance of the individual's mother or close kin. In the unpredictable real world, the age when the individual can acquire crucial knowledge is variable; the design of the developmental process reflects that uncertainty.

In contrast to those processes fine-tuned by experience, cleaning the body is not generally something that requires special skills tailored to local conditions. Indeed, grooming among mammals has almost all the various defining characteristics of the old-fashioned notion of instinct. Rodent grooming is, for example, a species-typical, stereotyped system of behavior that develops before it is of any use to the individual.

In other words, biologists expect variation in the way behavioral patterns and their underlying structure develop. Attempts to shoehorn each example into one of the two categories are ridiculous.

The muddled use of 'instinct' (and with it, 'innate' and 'inborn') does not mean that the expression of each behavioral characteristic is, what Salman Rushdie called in another context, a P2C2E – a process too complicated to explain. Nor does it mean that such expressions cannot be subject to evolution when critical environmental conditions are stable from one generation to the next. And it certainly does not mean that all adult behavior is totally dependent on the environment. What we must conclude is that if we want to understand developmental processes then we have no alternative but to study them.

Plant and animal breeders know well that many of the characteristics that matter to them are inherited. Long before genes were postulated and DNA was discovered, breeders took this as a bountiful fact of life, even though they had no idea how inheritance worked. To take just one example, dogs have for many centuries been bred for their behavioral characteristics as well as their appearance. The sheepdog is especially sensitive to the commands of humans, waiting until the shepherd gives it a signal to start herding the sheep. The pointer is especially attentive to the presence of certain game, stopping in its tracks when it detects the smell of a species such as grouse. Valued behavioral characteristics such as these are clearly inherited and are quickly lost if breeds are crossed with others.

Humans may also reveal through their children how particular characteristics are inherited. Two healthy parents from a part of the world where malaria is rife may have a child who develops severe anaemia. Both parents carry a gene that has some effect on red blood cells, protecting them against the malarial parasite that enters those cells during part of its life cycle. However, a double dose of this recessive gene leads to the red blood cells collapsing from their normal disc shape into strange sickle-like shapes. The child who receives this genetic legacy has sickle-cell anaemia.

Few behavioral characteristics are inherited in as simple a fashion as sickle-cell anaemia, and when they are, the effects are usually damaging and pervasive. A well-known case is the disabling disease phenylketonuria (PKU). If a child inherits two copies of a particular recessive gene from both parents, the child cannot produce a crucial enzyme required to break down phenylalanine, an amino acid that is a normal component of the average diet. The resulting accumulation of phenylalanine in the body poisons the child's developing brain and causes severe mental retardation – unless the condition is diagnosed and the child is given a special diet.

Evidence for genetic influences on human behavior is usually indirect. It is bound to be so, because naturally occurring breeding experiments are rare, and deliberate breeding experiments in the interest of genetic research would obviously be prohibited in most societies. However, the study of twins has cast some light on the links between genes and behavior.

Research into the inheritance of human behavior has been greatly helped by comparing genetically identical twins with nonidentical twins. Identical (or monozygotic) twins are genetically identical because they develop from the splitting of a single fertilized egg; they are naturally occurring clones. Nonidentical (or dizygotic) twins, in contrast, develop from two fertilized eggs. Consequently, they are no more similar to each other genetically than any two siblings born at different times. If identical twins are no more alike than nonidentical twins in a given behavioral characteristic, then the genetic influence on that characteristic is presumably weak. Conversely, when identical twins are substantially more alike than nonidentical twins (or siblings) in a behavioral characteristic, then the mechanism of inheritance is likely genetic.

Another way of exploring how genes influence behavior is to compare twins who have been reared apart with twins who have been reared together. The thought behind this approach is that separation in early infancy removes the influence of the shared environment, leaving only the inherited factors. The thought is not wholly correct, however, because even twins who are separated immediately after birth will have shared a common environment for the first crucial nine months after conception, while they are together in their mother's womb. This obvious truth can add to the difficulties of sorting out the sources of individual distinctiveness. Moreover, being separated at birth does not preclude the possibility that the different environments in which the twins are raised may in fact have many important features in common.

Nevertheless, the appearance, behavior, and personality of identical twins who have been reared apart are often startlingly similar. In one documented case, for example, a pair of twins had been separated early in life, one growing up in California, the other in Germany. Yet when they met for the first time in thirty-five years, they both arrived wearing virtually identical clothes and with similarly clipped moustaches; both had a habit of wrapping elastic bands around their wrists; and both had the idiosyncratic habit of flushing lavatories before as well as after using them.

Accounts such as these are sometimes greeted with skepticism, because it is suspected that in the interest of a good story only the startling matches have been reported while the discrepant twins have been ignored. Nevertheless, some properly conducted statistical surveys have revealed that, on a range of measures of personality, identical twins who have been reared apart are more like each other than nonidentical twins also reared apart. When making such comparisons, it does not matter whether, as has often been argued, the measures of behavioral characteristics are crude and relatively insensitive. The inescapable conclusion is that some observable aspects of individual behavior are influenced by inherited factors.

Even the most cursory glance at humanity reveals the enormous importance of each person's experience, upbringing, and culture. Look at the astonishing variation among humans in language, dietary habits, marriage customs, child-care practices, clothing, religion, architecture, art, and much else besides. Nobody could seriously doubt the remarkable human capacity for learning from personal experience and learning from others.

Early intervention can benefit the disadvantaged child, but in ways that had not been fully anticipated. In the 1960s, great efforts were made in the United States to help people living in difficult and impoverished conditions. The government program known as Head Start was designed to boost children's intelligence by giving them educational experience before starting school. But the program did not seem to have the substantial and much hoped-for effects on intelligence, as measured by IQ. Children who had received the Head Start experience displayed an initial modest boost in their IQ scores, but these differences soon evaporated after a few years. The fashionable response was to disparage such well-meaning efforts to help the disadvantaged young.

Later research, however, has revealed that some of the other effects of the Head Start experience were long-lasting and of great social significance – greater, in fact, than boosting IQ scores. Several long-term follow-up studies of people who had received preschool training under Head Start found they were distinctive in a variety of ways, perhaps the most important being that they were much more community-minded and less likely to enter a life of crime. Head Start produced lasting benefits for its participants and for society more generally, but not by raising raw IQ scores. Evidence for the long-term benefits of early educational intervention has continued to accumulate. Studies like these raise many questions about how early experiences exert their effects, but they do at least show how important such experiences can be.

Even relatively subtle differences in the way children are treated at an early age can have lasting effects on how they behave years later. One study compared the long-term effects of three different types of preschool teaching. In the first type, three- and four-year-olds were given direct instruction, with the teachers initiating the children's activities in a strict order; in the second, the teachers responded to activities initiated by the children; and in the third, known as High/Scope, the teachers involved the children in planning the activities, but arranged the classroom and the daily routine so the children could do things that were appropriate to their stage of development. Striking differences were found between the children as they grew up. When followed up at the age of twenty-three, the individuals who had been in the direct instruction group were worse off in a variety of ways than those in the other two groups. In particular, they were more likely to have been arrested on a criminal charge and more likely to have received special help for emotional impairment. In comparison, the individuals who had received the more relaxed type of preschooling were more likely to be living with spouses and much more likely to have developed a community spirit.

The importance of both genes and environment to the development of all animals, including humans, is obvious. This is true even for apparently simple physical characteristics – take myopia, or shortsightedness, for example. Myopia runs in families, suggesting that it is inherited, but it is also affected by individual experience. Both a parental history of myopia and, to a lesser extent, the experience of spending prolonged periods studying close-up objects will predispose a child to become shortsighted.

A more interesting case is musical ability, about which strong and contradictory views are held. Dissociation between general intellectual ability and musical ability is strongly suggested by the phenomenon of the musical idiot savant – an individual with low intelligence but a single, outstanding talent for music. Such individuals are usually male and often autistic, and their unusual gift (whether it be for music, drawing, or mental arithmetic) becomes apparent at an early age and is seldom improved by practice. One typical individual could recall and perform pieces of music with outstanding skill and almost perfect pitch; he had poor verbal reasoning, but that was to some degree offset by high levels of concentration and memory.

Children who are good at music, on the other hand, also tend to be good at reading and to have a good sense of spatial relations. The main factors fostering the development of musical ability form a predictable cast: a family background of music, practice (the more the better), practical and emotional support from parents and other adults, and a good relationship with the first music teachers. Practice is especially important, and attainment is strongly correlated with effort. A rewarding encounter with an inspirational teacher may lock the child into years of effort, while an unpleasant early experience may cause the child to reject music, perhaps forever. Here, as elsewhere, chance plays a role in shaping the individual's development.

Research on identical and nonidentical twins has shown that the shared family environment has a substantial influence on the development of musical ability, whereas inherited factors exert only a modest effect. Genetically identical twins are only slightly more alike in their musical ability than nonidentical twins or siblings. A study of more than six hundred trainee and professional musicians analyzed the origins of perfect pitch, the ability to hear a tone and immediately identify the musical note without reference to any external comparison. Heritable factors appeared to play a role, as musicians with perfect pitch were four times more likely than other musicians to report having a relative with that skill. But the same study also found that virtually all the musicians with perfect pitch had started learning music by the age of six. Of those who had started musical training before the age of four, 40 percent had developed perfect pitch, whereas only 3 percent of those who had started training after the age of nine possessed the ability. So early experience is also important.

Like many other complex skills, musical ability develops over a prolonged period; and the developmental process does not suddenly stop at the end of childhood. Expert pianists manage to maintain their high levels of musical skill into old age despite the general decline in their other faculties. They achieve this through copious practice throughout their adult life; the more frequent the practice, the smaller the age-related decline in musical skill. Practice not only makes perfect, it maintains perfect.

Is it possible to calculate the relative contributions of genes and environment to the development of behavioral patterns or psychological characteristics such as musical ability? Given the passion with which clever people have argued over the years that either the genes or the environment are of crucial importance in development, it is not altogether surprising that the outcome of the nature-nurture dispute has tended to look like an insipid compromise between the two extreme positions. Instead of asking whether behavior is caused by genes or the environment, the question became: How much is due to each? Within a single individual this question cannot be answered, but it can be posed for a population of individuals as follows: How much of the variation between individuals in a given characteristic is due to differences in their genes, and how much is due to differences in their environments?

The nature-nurture controversy appeared at one time to have been resolved by what seemed like a neat solution to this question about where behavior comes from. The suggested solution was provided by a measure called heritability. The concept of heritability is best illustrated with an uncontroversial characteristic such as height, which clearly is influenced by both the individual's family background (genetic influences) and nutrition (environmental influences). The variation between individuals in height that is attributable to variation in their genes may be expressed as a proportion of the total variation within the population sampled. This index is known as the heritability ratio. If people differed in height solely because they differed genetically, the heritability of height would be 1.0; if, on the other hand, variation in height arose entirely from individual differences in environmental factors such as nutrition, then the heritability would be 0.

Calculating a single number to describe the relative contributions of genes and environment has obvious attractions. Estimates of heritability are of undoubted value to animal breeders, for example. Given a standard set of environmental conditions, the genetic strain to which a pig belongs will predict its adult body size better than other variables such as the number of piglets in a sow's litter. If the animal in question is a cow and the breeder is interested in maximizing its milk yield, then knowing that milk yield is highly heritable in a particular strain of cows under standard rearing conditions is important.

Behind the deceptively plausible ratios lurk some fundamental problems. For a start, the heritability of any given characteristic is not a fixed and absolute quantity – tempted though many scientists have been to believe otherwise. Its value depends on a number of variable factors, such as the particular population of individuals that has been sampled. For instance, if heights are measured only among people from affluent backgrounds, then the total variation in height will be much smaller than if the sample also includes people who are small because they have been undernourished. The heritability of height will consequently be larger in a population of exclusively well-nourished people than it would be among people drawn from a wider range of environments. Conversely, if the heritability of height is based on a population with relatively similar genes – say, native Icelanders – then the figure will be lower than if the population is genetically more heterogeneous; for example, if it includes both Icelanders and African Pygmies. Thus, attempts to measure the relative contributions of genes and environment to a particular characteristic are highly dependent on who is measured and under what conditions.

Another problem with the heritability ratio is that it says nothing about the ways in which genes and environment contribute to the biological and psychological processes involved in an individual's development. This point becomes obvious when considering the heritability of a characteristic such as 'walking on two legs.' Humans walk on less than two legs only as a result of environmental influences such as war wounds, car accidents, disease, or exposure to teratogenic toxins before birth. In other words, all the variation within the human population results from environmental influences, and consequently the heritability of walking on two legs is zero. And yet walking on two legs is clearly a fundamental property of being human, and is one of the more obvious biological differences between humans and other great apes such as chimpanzees or gorillas. It obviously depends heavily on genes, despite having a heritability of zero. A low heritability clearly does not mean that development is unaffected by genes.

If a population of individuals is sampled and the results show that one behavioral pattern has a higher heritability than another, this merely indicates that the two behavioral patterns have developed in different ways. It does not mean that genes play a more important role in the development of the behavioral pattern with the higher heritability. Important environmental influences might have been relatively constant at the stage in development when the more heritable pattern would have been most strongly affected by experience.

The most serious shortcoming of heritability estimates is that they rest on the spurious assumption that genetic and environmental influences are independent of one another and do not interact. The calculation of heritability assumes that the genetic and environmental contributions can simply be added together to obtain the total variation. In many cases this assumption is clearly wrong.

One surprising conclusion to emerge from studies of identical twins is that twins reared apart are sometimes more like each other than those reared together. To put it another way, rearing two genetically identical individuals in the same environment can make them less similar rather than more similar because one of the twins is dominant to the other, entering the room first and speaking for them both. This fact pleases neither the extreme environmental determinist nor the extreme genetic determinist.

The environmental determinist supposes that twins reared apart must have different experiences and should therefore be more dissimilar in their behavior than twins who grew up together in the same environment. The genetic determinist does not expect to find any behavioral differences between genetically identical twins who have been reared together. If they have had the same genes and the same environment, how can they be different?

Siblings are less like each other than would be expected just by chance. The child picks a niche for him or herself, not on the basis of his own characteristics but on what his siblings have done. Individual differences emerge because children are active agents in their own development; children seek out their own space. When Mary did well at art, her younger sister Susan would not have anything to do with drawing or painting, even though she would probably have been good at both. When Henry developed a flair for history and languages, George inclined toward math and science. Most parents with more than one child can tell such stories.

Such interplay between siblings probably accounts for some of the influences of birth order. Other things are also at work, of course. Parents treat their successive children differently – sometimes deliberately, sometimes unwittingly. They often have a more taut relationship with their first child than with their later-born children; they are usually more relaxed, positive, and confident with their subsequent children, and their preoccupation with every detail of their children's behavior and appearance lessens. These examples emphasize how important it is that we look carefully at the transactions between the developing child and the social and physical worlds in which he or she lives.

The origins of human differences

Any scientific investigation of the origins of human behavioral differences eventually arrives at a conclusion that most nonscientists would probably have reached after only a few seconds' thought: genes and the environment both matter. How much each of them matters defies an easy answer, and we have to accept that no simple formula can solve that conundrum. We also have to wean ourselves away from the confused and utterly false idea that genes give rise to instincts and experience gives rise to acquired behavior. The answer to the question of where knowledge comes from will not emerge from the conventional opposition between nature and nurture. The answer requires understanding of the biological and psychological processes that build a unique adult from a fertilized egg.

As attention is focused on development of behavior, more and more will be learned about the underlying processes. My own view is that many of these have regularities that will be amenable to analysis. But it does not follow that as these regularities are uncovered human behavior will become more predictable. To understand why, consider a rule-governed game like chess. It is impossible to predict the course of a particular chess game from a knowledge of the game's rules. Chess players are constrained by the rules and the positions of the pieces, but they are also instrumental in generating the positions to which they must subsequently respond. The range of possible games is enormous. The rules may be simple but the outcomes can be extremely complex.

The adult human brain, on which its owner's behavior depends, has around one hundred thousand million (10^{11}) neurons, each with hundreds or thousands of connections to other neurons. A diagram of even a tiny part of the brain's connections would look like an enormously complex version of a map of the New York subway system. The brain is organized into subsystems, many of which are dedicated to different functions that may run separately but, if the behavior of the individual is not to be a mess, must be integrated with each other. The products of genes, the impact of experience, and the resulting activities of neurons are all embedded in elaborate networks.

The idea that genes might be likened to the blueprint of a building is hopelessly misleading because the correspondences between plan and product are not to be found. In a blueprint, the mapping works both ways. In a finished house, the position of each room can be found on the blueprint, and the blueprint indicates where every room will be. This straightforward mapping is not true for genes and behavior, in either direction. The language of a gene *for* a particular behavior pattern, so often used by scientists, is exceedingly muddling to the nonscientist (and, if the truth be told, to many scientists as well). This is because the phraseology seems to imply that the gene determines the characteristic of the behavior without anything else being important. What the scientists mean (or should mean) is that a genetic difference between two groups is associated with a difference in behavior. They know perfectly well that other things are important and that, even in constant environmental conditions, the developmental outcome depends on the whole 'gene team.'

Nevertheless, it is likely that order underlies even those learning processes that make people different from each other. Knowing something of the underlying regularities in development does bring an understanding of what happens to the child as he or she grows up. The rules influence the course of a life, but they do not determine it. Like chess players, children are active agents. They influence their environment and are in turn affected by what they have done. Furthermore, children's responses to new conditions will, like chess players' responses, be refined or embellished as children gather experience. Sometimes normal development of a particular ability requires input from the environment at a particular time; what happens next depends on the character of that input.

The upshot is that, despite their underlying regularities, developmental processes seldom proceed in straight lines. Big changes in the environment may have no effect whatsoever, whereas some small changes have big effects. The only way to unravel this is to study what happens.