Psychological Review
1994, Vol. 101, No. 4, 568–586

0033-295X/94/$3.00

Nature–Nurture Reconceptualized in Developmental Perspective: A Bioecological Model

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In response to Anastasi's (1958) long-standing challenge, the authors propose an empirically testable theoretical model that (a) goes beyond and qualifies the established behavioral genetics paradigm by allowing for nonadditive synergistic effects, direct measures of the environment, and mechanisms of organism–environment interaction, called *proximal processes,* through which genotypes are transformed into phenotypes; (b) hypothesizes that estimates of heritability (e.g., h^2) increase markedly with the magnitude of proximal processes; (c) demonstrates that heritability measures the proportion of variation in individual differences attributable only to *actualized* genetic potential, with the degree of *nonactualized* potential remaining unknown; (d) proposes that, by enhancing proximal processes and environments, it is possible to increase the extent of actualized genetic potentials for developmental competence.

Three-and-a-half decades ago, Anne Anastasi (1958), in an article published in this journal, posed a challenge to psychological science. The challenge appeared in the title of her article: "Heredity, Environment, and the Question: 'How?' " Anastasi offered few answers. Instead, she urged her scientific colleagues to pursue what she saw as a more rewarding and necessary scientific goal.

> [Rather than seeking] to discover *how much* of the variance was attributable to heredity and how much to environment . . . a more fruitful approach is to be found in the question *"How?"* There is still much to be learned about the specific *modus operandi* of hereditary and environmental factors in the development of behavioral differences. (p. 197)

Today, 35 years later, the challenge still stands, despite the fact that recent developments in science and society give it renewed importance. Thus, over the past decade, research not only in behavioral genetics but also human development has placed increased reliance on the model of classical, additive behavioral genetics ("Ability Testing," 1992; Plomin, 1993; Plomin & Bergeman, 1991; Plomin & McClearn, 1993; Scarr, 1992). The extensive body of work guided by this model has pushed the frontiers of knowledge but, particularly in relation to some of the general conclusions drawn from it, has evoked vigorous criticism, not only on scientific but also on social and ethical grounds (Baumrind, 1993; Hoffman, 1994; Jackson, 1993; Lerner & von Eye, 1992).

In our view, although the traditional model has made important contributions to the understanding not only of genetic but also of environmental influences on human development (e.g., Plomin & Daniels, 1987), it nevertheless remains incomplete. In addition, some of its basic assumptions are subject to question. At the core of the problem lies precisely Anastasi's issue: the need to identify the mechanisms through which genotypes are transformed into phenotypes.

That is the task that we essay in this article. We do not claim to present a definitive model; rather, we propose a general theoretical and operational framework and a set of testable hypotheses that—whether or not they pass the test—we believe will point the way for further scientific advances.

Overview

To foreshadow our argument and evidence, and taking as a point of departure a *bioecological paradigm* of human development (Bronfenbrenner, 1989a, 1993, 1994; Ceci, 1990, 1993), the proposed model extends and redefines several of the key assumptions underlying the classical paradigm of behavioral genetics to arrive at formulations we believe to be more consonant with contemporary theory and research in human development. In addition to incorporating explicit measures of the environment conceptualized in systems terms, and allowing for nonadditive, synergistic effects in genetics–environment interaction, the model posits empirically assessable mechanisms, called *proximal processes,* through which genetic potentials for *effective* psychological functioning are actualized.

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Some of the ideas presented in this exposition were first introduced in a brief prospective article by Bronfenbrenner and Ceci (1993).

Of the many colleagues at home and abroad who generously commented on earlier drafts of this article, only a few can be mentioned here. We are especially indebted for their challenging, constructive criticisms to Anne Anastasi, Jay Belsky, Maggie Bruck, Glen Elder, Siv Fischbein, Gilbert Gottlieb, Robert Plomin, Rainer Silbereisen, Michael Rutter, Laurence Steinberg, Theodore Wachs, and four anonymous reviewers. The final responsibility, of course, lies with the authors. We are also grateful to Steven Small and Thomas Luster for copies of the original tapes from Small's extensive surveys of Wisconsin adolescents. Last but not least, we are indebted to our students Kristen Jacobson and Tara White for their ingenuity and persistence in managing to translate massive data tapes from one computer language to another and for carrying out basic analyses.

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In the preceding paragraph, the word *effective* is emphasized to indicate that proximal processes as we have defined them are presumed to lead to particular kinds of developmental outcomes—those that represent the actualization of potentials for (a) differentiated perception and response; (b) directing and controlling one's own behavior; (c) coping successfully under stress; (d) acquiring knowledge and skill; (e) establishing and maintaining mutually rewarding relationships; and (f) modifying and constructing one's own physical, social, and symbolic environment.

This formulation implies that when proximal processes are weak, genetically based potentials for effective psychological functioning remain relatively unrealized but that they become actualized to a progressively greater extent as proximal processes increase in magnitude.[1] A set of verifiable hypotheses derived from the bioecological model predict systematic variation in the extent of such actualization as a joint function of (a) proximal processes, (b) their stability over time, (c) the environmental contexts in which they take place, (d) the characteristics of the persons involved, and (e) the nature of the developmental outcome under consideration. We also propose a corresponding series of research designs through which these hypotheses can be investigated. In each instance, the primary criterion for assessing the impact of the postulated mediating forces on the actualization of genetic potentials is that used in the classical behavioral genetics model, namely, the level of *heritability.*

Heritability is defined as "the proportion of the total phenotypic variance that is due to additive genetic variation" (Cavalli-Sforza & Bodmer, 1971, p. 536). There are a number of methods for estimating this proportion (referred to by the symbol h^2), depending on the degree of genetic relationship between the parties involved. In the case of monozygotic versus dizygotic twins, the formula most commonly used is computed as follows:

$$h^2 = 2(r_{mz} - r_{dz}),$$

where r_{mz} and r_{dz} are the intraclass correlations for a given developmental outcome between pairs of monozygotic (mz) and same-sex dizygotic (dz) twins, respectively. In effect, what the formula accomplishes is to estimate how much of an increase in similarity between individuals is achieved given that the genetic component is twice as great for identical twins as for fraternal twins.[2] Moreover, it is this increase in similarity, as measured by h^2, that (assuming equal environments) is interpreted in the established behavior genetics model as indicating the proportion of individual variation in a given human characteristic that is attributable entirely to genetic endowment, free from any environmental influence.

Heritability: Cons and Pros

It is important to point out at the outset that a measure of heritability, although appropriate for our intended purpose, nevertheless has some serious shortcomings. To begin with, it taps only one of the spheres in which genetic influences exert their developmental power. Thus, as already indicated, heritability, in both its conceptual and operational definitions, describes only the extent to which genetic endowment contributes to observed differences in developmental outcome between individuals growing up in the same environments. It provides no information whatsoever about another domain in which genetics can exert an important effect—observed differences in developmental outcome between groups of persons growing up in different environments (e.g., as the result of genetic selection).

Measures of heritability have other consequential limitations as well. For instance, values of h^2 for the same developmental outcome are known to vary from one population to the next, giving rise to the necessary qualification that heritability is specific to the population on which it is calculated (Cavalli-Sforza & Bodmer, 1971; Bouchard & Segal, 1985; Plomin, DeFries, & McClearn, 1990). However, as yet, there are very few studies in which the extent of this variation has been systematically examined, let alone analyzed in terms of the characteristics of the population or of the environment in which the population lives that might account for the observed variability in the value of h^2. In the proposed bioecological model, presumed major sources of such variability are incorporated as key elements in the design.

A further limitation of heritability is that it deals only with individual differences and hence can tell us nothing about the absolute level of competence around which the individual variation is occurring.

A telling example[3] is provided in a Gedanken Experiment suggested by Hebb (1970) and originally inspired by Mark Twain:

> Mark Twain once proposed that boys should be raised in barrels to the age of 12 and fed through the bung-hole. Suppose we have a 100 boys reared this way, with a practically identical environment. Jensen agrees that environment has *some* importance (20% worth?), so we must expect that the boys on emerging from the barrels will have a mean IQ well below 100. However, the variance attributable to the environment is practically zero, so on the "analysis of variance" argument, the environment is not a factor in the low level of IQ, which is nonsense. (p. 578)

In the above example, the value of h^2 would be close to one, with virtually all of the variability arising from differences in genetic endowment.

Whereas in the preceding case high heritability was associated with a reduced level of development, the next example documents the very opposite. It also takes one from the world of scientific imagination into that of scientific fact—specifically, the occurrence of a marked increase in the heights of second-generation Japanese persons raised in the United States, who were taller than both the American-reared sons of short Japanese fathers and the Japanese-reared sons of tall Japanese fathers—a result of differing nutrition. In the following passage, Ceci (1990) summarized the relevant findings and their implications with respect to heritability:

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[1] The formulation does not exclude the possibility of other mechanisms that activate genetic potentials for forms of behavior that are *destructive* to both the environment and the individual. In this exposition, however, we concern ourselves almost exclusively with potentialities for constructive development.

[2] For further discussion of the underlying assumptions and logic for estimating heritability and the derivation of alternative estimates of h^2 for different degrees of genetic relationship, see Falconer (1989) and Plomin, De Fries, and McClearn (1990).

[3] We are indebted to Professor Richard Lerner for bringing this example to our attention. It is cited in Lerner and von Eye, (1992, p. 23).

> Even though h^2 among this group remained over .90, the American-reared offspring were over five inches taller than they would have been if they had been reared in Japan (Greulich, 1957). And Tanner (1962) showed that both American and British teenagers were a half-foot taller, on average, than their predecessors a century earlier. Finally, Angoff (1988) reported that heights of young adult males in Japan were raised by about three and a half inches since the end of World War II, an enormous gain in such a brief period of time! If something as highly heritable as height can fluctuate so dramatically in such a short period of time, then surely traits like intelligence can be altered, too. (p. 142)

What both of the cited examples indicate is that conditions and processes in the environment can influence substantially the degree of heritability. In the case of height, some of those conditions and processes are known (e.g., particular changes in diet). With respect to the heritability of most psychological outcomes, however, the extent of susceptibility to environmental influences is still to be determined. Within the framework of the proposed bioecological model, we offer a series of testable hypotheses about the nature of such environmental influences and the extent of their power to actualize individual differences in genetic potentials for human competence.

Last, and perhaps most important, heritability is limited because it assesses differences only in *actualized* genetic potential; the extent of *nonactualized* potential remains unknown. Thus, contrary to the claims of some influential scholars (e.g., Scarr, 1992), the magnitude of h^2 does not set, by itself, any upper limit on what the ultimate human potential for development might be.

All this does not mean, however, that because of such limitations, the concept of heritability has no clear or useful scientific meaning and therefore should be abandoned—a position, in effect, taken by some recent critics (e.g., Baumrind, 1993; Hoffman, 1994; Jackson, 1993; Lerner & von Eye, 1992). We disagree with this position. In our view, the concept of heritability, and its operationalization in the form of h^2, does permit the valid assessment of one particular manifestation of genetic potential that has considerable importance for psychological development. To the extent that human beings differ in their innate capacity for realizing individual talents and buffering against dysfunction, it is important to understand under what circumstances such constructive potentials find expression. When analyzed within the framework of the proposed bioecological model, heritability coefficients provide the best scientific tool presently available for assessing the extent to which particular environments and psychological processes foster or impede the actualization of individual differences in genetic potential for effective development.

Accordingly, each of the hypotheses we present is accompanied by a research design that includes as a key component a test of the prediction that heritability (assessed by h^2) varies markedly and systematically as a function of levels of proximal process and of environmental conditions specified in the hypothesis under consideration.

Finally, in our view, heritability can make its clearest and most valuable scientific contribution when it is incorporated as a key element of the bioecological model, where, paradoxically, some of its liabilities are turned into assets. This comes about in the following way: If our assumption is correct that proximal processes serve as mechanisms for actualizing genetic potential, then increased levels of proximal process should lead not only to higher levels of heritability but also to more advanced levels of developmental functioning. Hence, it is only when this dual effect occurs that there are grounds for assuming that genetic potential for effective developmental functioning has been actualized. One result without the other is not sufficient. As we have seen, a high level of heritability, taken by itself, has no clear meaning because it can be associated with both high and low levels of developmental functioning. In a similar manner, an increase in the level of developmental functioning, per se, cannot be assumed to be the product of emergent genetic factors because it could simply result from improved environmental conditions. However, when the operation of the same mechanism—namely, an increase in proximal process—leads both to higher heritability and to a more advanced level of psychological development, then there is at least presumptive evidence that some actualization of genetic potential has occurred.

At the same time, viewed from a bioecological perspective, proximal processes alone do not tell the whole story, for both their magnitude and their developmental effectiveness are presumed to vary as a joint function of the characteristics of the environment in which they take place, the persons living in that environment, and the nature of the developmental outcomes under investigation.

The foregoing considerations necessarily impose some requirements on the design of a theoretical and operational model for their investigation that, in several important respects, go beyond those incorporated in the established behavioral genetics paradigm. We conclude our overview with a brief summary of these additional features.

Distinctive Characteristics of the Bioecological Model

First and foremost, the model proposes and provides for the assessment of mechanisms, called *proximal processes,* through which genetic potentials are actualized.

Second, it presents a conceptual framework that stipulates systematic variation in heritability as a joint function of proximal processes and characteristics of the environment in which these processes take place.

Third, albeit to a more limited extent, the model deals with variation in heritability as a function of the nature of the developmental outcomes under consideration.

Fourth, for each observed value of heritability, the model also provides an assessment of the absolute level of developmental functioning around which the genetically based individual differences are occurring.

Finally, the bioecological model also addresses what is probably the most serious and problematic limitation of the established behavioral genetics paradigm, namely, that heritability measures only the proportion of variation attributable to individual differences in actualized genetic potential; the extent of nonactualized potential remains unknown. The ultimate solution to this problem will doubtless have to wait on the development of biogenetic methods for assessing human genotypes (e.g., mapping of the human genome). However, in the meantime, we suggest that the investigation of what we have called proximal processes, and their developmental consequences under different environmental conditions, offers an indirect strategy for testing the limits of the unquestionably substantial role of both genetics and environment in contributing to individual differences in psychological growth.

The rationale for this strategy has its origins in the concept of *reaction range,* first proposed shortly after the turn of the century by the German zoologist Richard Woltereck (1909). The term refers to the variety of alternative phenotypic outcomes set by a given genotype (cf. Gottesman, 1963; Platt & Sanislow, 1988). More recently, Albersch (1983), Gottlieb (1991), and others (e.g., Subtelny & Green, 1982) have emphasized that genetic activity does not produce finished traits but rather interacts with experiential factors (e.g., Gottlieb's *experiential canalization*) in determining developmental outcomes. Moreover, a notion broadly comparable to such positions regarding genetic potential can also be found in work in embryology. The concept of *presumptive neural tissue* refers to the ability of early transplanted embryological tissue to be altered in its ultimate effect by placing it in a new location in a host embryo—its internal environment (see Kandel, Schwartz, & Jessell, 1991).

We take issue, however, with the prevailing conception of the reaction range simply as a curved plane, similar to a bent piece of chicken wire that quickly straightens out to become horizontal (e.g., see Figure 1 in Turkheimer & Gottesman, 1991, p. 19). This representation reflects the commonly held position among behavioral geneticists that environment exerts an important influence only in severely deprived environments (the bent edge of the chicken wire) and has but small effects through the rest of its more extensive range.[4] We call this basic assumption into question on two grounds. First, we propose hypotheses that, if supported, will demonstrate that proximal processes can produce substantial variation in heritability even in advantaged environments (i.e., over the entire plane). Second, we take exception to the depiction of the reaction norm for psychological outcomes as "flat across a wide range of environments" (Turkheimer & Gottesman, p. 19), arguing, along with Cairns (1991), that there is considerable variation in the reaction norm depending on the specific characteristics of the environment and the nature of the outcome. In Cairns's words:

> For my money, the biggest flaw in the landscape metaphor is not its genetic bias or its too-rigid view of developmental sequences. Rather, it is that the metaphor has been applied to the development of whole organisms and whole systems rather than to particular processes. Development has multiple facets, and the description of particular features may be distorted by assuming a single trajectory for the whole and all of its parts. (p. 24)

Our view of the sources of such variation is even more specific. It focuses on "how" particular kinds of genetic potentials are actualized, through proximal processes, to take particular phenotypic forms of effective psychological functioning. We have already proposed our indirect research strategy for answering this question. It is based on the thesis that the effect of increased levels of proximal processes is manifested in two ways. First, such processes foster the development of effective psychological functioning. Second, if we are correct in our claim that proximal processes are mechanisms through which genotypes are transformed into phenotypes, then increased levels of proximal processes should also result in higher levels of heritability. We presume that the occurrence of this dual effect indicates that the actualization of genetic potentials for more advanced developmental functioning has, in fact, taken place.

As we document later, the first of these two predictions is supported by a growing body of research. With respect to the second, however, despite an intensive search, we have not been able to find any studies in which data on heritability and degree of exposure to proximal process are available for the same set of subjects.[5] Hence, the research designs for each of the hypotheses presented here involve a two-stage sequence. Stage 1 documents the power and differential developmental impact of proximal processes taking place in systematically contrasting types of environments. Stage 2 introduces an additional dimension into the design that permits the assessment of the effect of the proximal process on the actualization of genetic potential by including in the sample groups that vary systematically in degree of consanguinity (e.g., identical and fraternal twins; and own biological, adopted, or stepchildren). To our knowledge, no samples meeting these dual requirements presently exist.

This means that, at least as yet, none of the specific hypotheses set forth in this exposition has been fully tested. In each case, some research findings are presented in support of Stage 1. With respect to Stage 2, however, the most we can do is to cite what might be called circumstantial evidence—consistent but not compelling. This possibility arises because there are a few studies that report heritability coefficients for groups that can be presumed to differ in the degree of exposure to proximal processes (e.g., families living in advantaged versus disadvantaged social environments). Wherever appropriate, the data from these studies are used to provide an approximate test of Stage 2 for the hypothesis under consideration.

In sum, the purpose of our exposition is to provide a theoretical and operational model that can serve as a basis—and we hope also as an incentive—for future research.

The Bioecological Model: Defining Properties

The derivation of specific hypotheses, and the research designs to be used for their investigation, is best explained by a more full and systematic exposition of the bioecological model as a whole.

Underlying the bioecological model is a cardinal theoretical principle emerging from research on theories of genetic transmission, namely, that genetic material does not produce finished traits but rather interacts with environmental experience in determining developmental outcomes (Albersch, 1983; Cairns, 1991; Gottlieb, 1991, 1992; Subtelny & Green, 1982; Turkheimer & Gottesman, 1991). Indeed, this interactive process is already operative in the earliest stages of embryological development. An example is the phenomenon of presumptive neural tissue already mentioned (Kandel, Schwartz, & Jessell, 1991).

What are the implications of this principle in the psychological realm? What does it mean for the development of the basic

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[4] For an even more extreme formulation of this position, see Scarr (1992).

[5] The closest approximation is found in a study by Fischbein and her colleagues (Fischbein, Gutman, Nathan, & Eraschi, 1990); for a description, see later.

psychological processes of perception, cognition, emotion, and motivation? The principle implies that at the level of the genetic material itself these classical processes do not yet exist as such. Psychological processes involve psychological content; they are *about* something. At the beginning, that content is in the outside world. More specifically, in our species the content turns out to be mainly about people, objects, and symbols. Initially, these entities exist only in the environment, that is, outside the organism. Hence, from its beginnings, development involves interaction between organism and environment: The external becomes internal and becomes transformed in the process. However, because from the very beginning the organism begins to change its environment, the internal becomes external and becomes transformed in the process.

The bidirectional nature of these transformations is rooted in the fact that genetic potentials for development are not merely passive possibilities but active dispositions expressed in selective patterns of attention, action, and response. However, these dynamic potentials do not spring forth full-blown like Athena out of Zeus's head from a single blow of Vulcan's hammer. The process of transforming genotypes into phenotypes is neither so simple nor so quick. The realization of human potentials requires intervening mechanisms that connect the inner with the outer in a two-way process that occurs not instantly, but over time. That process is the focus of the first defining property of a bioecological model, formulated as follows:

> *Proposition 1:* Especially in its early phases, and to a great extent throughout the life course, human development takes place through processes of progressively more complex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate environment. To be effective, the interaction must occur on a fairly regular basis over extended periods of time. Such enduring forms of interaction in the immediate environment are referred to henceforth as *proximal processes.* Examples of enduring patterns of these processes are found in parent–child and child–child activities, group or solitary play, reading, learning new skills, problem solving, performing complex tasks, and acquiring new knowledge and know-how.[6]

Such processes serve to mobilize and sustain the developing organism's attention, instigate reaching slightly beyond current boundaries (Vygotsky's [1978] "zone of proximal development"), detect subtle relationships, and accumulate and refine both declarative and metaknowledge (Chi & Ceci, 1987). In general, to the extent that they occur in a given environment over time, proximal processes are postulated as the mechanisms through which human genetic potentials for effective psychological functioning are actualized.

In short, proximal processes are posited as the primary engines of effective development. Nevertheless, like all engines, they cannot produce their own fuel nor are they capable of self-steering. A second defining property identifies the three-fold source of these dynamic forces:

> *Proposition 2:* The form, power, content, and direction of the proximal processes effecting development vary systematically as a joint function of the characteristics of the developing person, of the environment—both immediate and more remote—in which the processes are taking place, and of the nature of the developmental outcomes under consideration.

A third defining property of the model specifies the presumed analogous set of relationships with respect to the role of proximal processes in actualizing genetic potential for effective developmental functioning.

> *Proposition 3:* Proximal processes serve as a mechanism for actualizing genetic potential for effective psychological development, but their power to do is also differentiated systematically as a joint function of the same three factors stipulated in Proposition 2.

Before discussing these propositions in the context of concrete research examples, some clarification of terms is in order. To begin with, Proposition 1 introduces a distinction not usually made in developmental research, but one that is fundamental to the bioecological model. Traditionally, such phenomena as mother–infant interaction—or, more generally, the behavior of other persons toward a child—have been treated under the more inclusive category of the environment. In the bioecological model, the two are distinguished conceptually, with the former regarded as a process, and the latter as the environment in which the process takes place. In addition, within the environmental sphere itself, a further differentiation is made between the immediate setting in which activities can take place (such as family, classroom, peer group, or work place) and the broader context in which the immediate setting is embedded (e.g., social class, ethnicity, culture, subculture, or historical period).

Taken together, the three foregoing propositions provide a basis for deriving specific hypotheses. The derivation of each hypothesis is presented within the context of a concrete research example. The hypotheses are formulated at three levels, moving from the more general to the more differentiated and complex.

Proximal Processes, Developmental Outcomes, and Heritability

The first hypothesis formulates a basic thesis of the bioecological model:

> *Hypothesis 1:* Proximal processes raise levels of effective developmental functioning, and thereby increase the proportion of individual differences attributable to actualized genetic potential for such outcomes. This means that heritability (h^2) will be higher when proximal processes are strong and lower when such processes are weak.

As previously indicated, each hypothesis involves a two-stage sequence. We begin with a concrete research example for Stage 1 documenting the effect of a proximal process on a subsequent developmental outcome. A number of such examples are presented, but for reasons that will become apparent, we begin with an actual experiment involving random assignment to treatment and control groups.

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[6] Note that such patterns of behavior as neglect, abuse, or domination necessarily imply low levels of proximal process because they reduce possibilities for progressively more complex reciprocal interaction. Indeed, we suggest that patterns of behavior that are predominantly unresponsive to the characteristics and actions of another person may be the principal mechanisms for actualizing genetic potentials for developmentally maladaptive and destructive responses toward both the environment and the self.

Example 1: Experimentally Induced Proximal Processes and Their Developmental Effects

Almost 2 decades ago, a Dutch developmental psychologist, Riksen-Walraven (1978), published an important investigation that is still little known in the United States.[7] Based on a sample of 100 nine-month-old infants and their mothers living in the city of Nijmegen, the research "was aimed at raising the responsiveness of parents and enhancing the amount of stimulation provided by them to their infants" (p. 111). Because previous studies had indicated that "working-class parents are less responsive to their infants . . . all subjects came from working-class families" (p. 111).

The mothers and their infants were randomly assigned to four groups of 25 dyads each. Mothers in what the author called the responsiveness group were given a workbook for parents stressing the idea that "the infant learns most from the effects of its own behavior" (p. 113). Specifically,

> Caregivers were advised not to direct the child's activities too much, but to give the child opportunity to find out things for himself, to praise him for his efforts, and to respond to his initiations of interaction. (p. 113)

By contrast, mothers of infants in the so-called stimulation group received a workbook that emphasized the importance of providing the infant with a great variety of perceptual experiences of all kinds, "to point to and name objects and persons" and "to speak a lot to their infants" (p. 112).

The experimental program for the third group was a combination of materials from the first and second programs. Finally, a matched control group did not receive any special treatment.

Follow-up observation and testing conducted in the home 3 months later revealed, first of all, that the instructions provided to the parents on the 1st day of the experiment had a substantial effect. The behaviors of the mothers in the several treatment groups differed not only significantly but markedly in accord with the orientation to which they had been exposed at the outset of the experiment. More important, infants of mothers who had been encouraged to be responsive to their babies' initiatives exhibited higher levels of exploratory behavior than any other group and were more likely to prefer a novel object to one that was already familiar. These babies also learned more quickly in a contingency task.

Note that, consistent with Proposition 1, the most successful experimental treatment engaged subjects in activities that required initiative and reciprocal interaction with their environment. Moreover, such engagement was not short-lived or ephemeral but continued on an everyday basis over a fairly extended period of time. More specifically, the results of Riksen-Walraven's experiment satisfy the requirements of Stage 1 of the Hypothesis 1 in showing that infants randomly assigned to the maternal responsiveness treatment (a proximal process) subsequently exhibited a higher level of cognitive development.

Completing the Model

To provide a test for Stage 2, the following additional features would have to be incorporated into the research design:

1. Include in the sample two groups that differ systematically from each other in degree of consanguinity but are comparable in other respects.
2. Assign one half of each group at random to the responsiveness treatment and the no-treatment control groups. (To keep the example simple, we omitted the other two experimental groups.[8])
3. For each of the two groups, calculate the heritability coefficient and the corresponding mean for the measure of cognitive development.

For Hypothesis 1 to be sustained, both the heritability coefficient and the mean of the cognitive measure should be markedly and significantly higher for the maternal responsiveness treatment than for the control group.[9]

Before completing discussion of Hypothesis 1, we have to deliver on a promissory note. The reader will recall that, in selecting the research example for this hypothesis, we deliberately chose a study based on a controlled experiment. Yet, most differences in level of proximal process, and their demonstrated developmental effects, do not occur as the result of experimental manipulation but rather as a product of natural variation in the settings of everyday life, such as the family (Baumrind, 1966, 1971, 1991; Dunham & Dunham, 1990, 1992; Dunham, Dunham, Hurshman, & Alexander, 1989; Kaye, 1982; Tulkin, 1977; Tulkin & Kagan, 1972), the school (Ceci, 1990, 1991; Comer, 1980; Rutter, Maughan, Mortimore, & Ousten, 1979),

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[7] We are indebted to our Cornell colleague Rick Canfield for bringing this study to our attention.

[8] Even so, the number of cells in the matrix poses the problem of obtaining sufficiently large numbers of cases in each. This difficulty may be obviated, to some extent, by three considerations. First, if it is true, as hypothesized, that higher levels of proximal process will produce substantial changes in the value of h^2, then significant differences may emerge even between subsamples of modest size. Second, although twins represent a comparatively small fraction of the total population, other types of consanguineous contrasts (e.g., full siblings versus half or adopted siblings) are becoming much more frequent because of the rapid changes in family structure occurring in contemporary societies (Bronfenbrenner, 1992). Finally, the use of a controlled experiment with random assignment appreciably increases the statistical power of the design.

[9] Two years earlier, apparently unbeknownst to Riksen-Walraven, two researchers at Yale University (Langer & Rodin, 1976; Rodin & Langer, 1977) had carried out an experiment essentially testing the same hypothesis, but with a sample at the opposite end of the age scale: residents of a nursing home for the elderly. The administrator of the facility gave a talk to residents in the experimental group emphasizing their responsibility for themselves, whereas the communication to a second comparison group stressed the staff's responsibility for them as patients. In a follow-up study conducted 18 months later, subjects in the experimental group were judged by observers blind to the experimental conditions to be more alert, sociable, and vigorous. The most striking results were seen in the comparison of death rates between the two treatment groups. In the subsequent 18 months following the intervention, 15% in the responsibility-induced group died, compared with 30% in the control group. If Hypothesis 1 is valid, then the heritability for both outcomes should be substantially higher for the experimental than for the control subjects. Moreover, in that case, the results of the two experiments taken together would indicate that the power of proximal processes to actualize genetic potential operates at both ends of the life course and, presumably, in between as well.

the adolescent peer group (Cairns, 1979; Cairns & Cairns, 1993; Sherif & Sherif, 1953; Steinberg, in press), and the adult workplace (Kohn, 1977; Kohn & Schooler, 1983; Kohn & Slomczynski, 1990; Luster, Rhoades, & Haas, 1989; Piotrkowski & Katz, 1983). In fact, all of the other studies cited later were conducted in such everyday settings. Why begin with an exception to the rule?

The reason for the choice does not reflect merely a general predilection for maximizing scientific rigor; rather, it represents a response to a specific challenge posed in a series of articles by Scarr and her colleagues (Scarr, 1985, 1992, 1993; Scarr & McCartney, 1983). They contended that parents construct environments for their children, and children construct their own environments primarily in response to their shared inherited predispositions. This would imply that proximal processes, which are reciprocal in nature, necessarily carry a significant genetic loading. This is certainly true; the question is, to what extent? In Scarr's view, the environment-genetics correlation is so strong that it leads her to the provocative conclusion that "environments that most parents provide for their children have few *differential* effects on their offspring" (1992, p. 3).

The results of Riksen-Walraven's experiment clearly demonstrate that this conclusion cannot be sustained. They also indicate that proximal processes can produce appreciable differences in developmental outcomes that cannot be attributed to genetic selection. These findings also imply that any effects of proximal processes on heritability—whether found in experimental or nonexperimental studies—cannot be interpreted solely as the products of a genetic component in proximal processes.

The Ecology of Heritability

In this section, we present two research examples illustrating the concepts and interrelationships incorporated in Proposition 2 and the specific hypothesis that this proposition generates. In accord with Proposition 2, the hypothesis deals with the effects of three elements in different combinations; as a result, its structure is rather complex. For this reason, we defer the formal statement of the full hypothesis until both examples, as well as their respective findings, have been described and discussed.

As before, each example consists of two stages: the first documents the effects of a proximal process on a particular developmental outcome (in this instance, in two or more contrasting environments); the second provides a research design for investigating analogous effects (again, in two or more environments) of the same proximal process on the level of heritability.

Example 2: Proximal Process and Children's Problem Behaviors

The data for this example are drawn from a longitudinal study by Drillien (1964) of factors affecting the development of children of low birth weight compared with those of normal birth weight. For present purposes, only the data for the latter are shown ($N = 164$). Figure 1 depicts the impact of the quality of mother–infant interaction at age 2 on the number of problem behaviors[10] observed at age 2 and again at age 4 as a function of social class. The measure of interaction was dichotomized (good process vs. poor process) by using the median for the sample as a whole as the cutting point.

As can be seen, in accord with Proposition 1, a proximal process—in this instance, mother–infant interaction across time—emerges as a powerful predictor of developmental outcome. At the same time, as stipulated in Proposition 2, the power of the process varies systematically as a joint function of the characteristics of the person (in this instance, age) and of the context (here represented by social class).

More specifically, first and foremost the results provide strong support for Stage 1 of Hypothesis 1. At each of the three social class levels, a higher level of proximal process is associated with a reduction in the number of problem behaviors exhibited by the child. Moreover, the proximal process appears to exert its greatest effect in the most disadvantaged environment, and this effect increases over time so that by age 4 the observed differences in problem behavior are appreciably greater than they were at age 2. Note also that the proximal process has the general effect of reducing, or buffering against, environmental differences in developmental outcome; specifically, under high levels of mother–child interaction, social class differences in problem behavior become much smaller.

But what about the possibility of genetic selection? Given that, on the average, mothers and their biologically related children share half of their genes in common, is it not likely that genetically responsive mothers will have genetically responsive children, that children who are innately prone to behavior problems will have mothers with a similar genetic constitution, and that, as a result, the observed relation of proximal processes to reduced problem behavior would involve a genetic component? In our view, unquestionably so, both in principle and, as has been demonstrated in a recent study, also in fact (Plomin, Reiss, Hetherington, & Howe, 1994).

But then having said this, how does one explain that, as seen in Figure 1, this relation is clearly strongest in the most disadvantaged environments? Even if one accepts the thesis of Jensen (1969, 1980) and others that social class is also a product of genetic selection, such that the proportion of innately less well-endowed persons is likely to be greater in lower class groups, this would not account for a higher genetic–environment correlation in that context. In short, it seems reasonable to conclude, even in the absence of experimental controls, that the observed relations between mother–infant interaction and subsequent developmental outcome documented in Figure 1 also involve an appreciable environmental component.

So much for the "good news"; now, for the "not so good." Even though proximal processes had their greatest developmental impact in the most disadvantaged environment, the average number of problem behaviors for all children in the lowest social class was nevertheless greater than for those in the highest socioeconomic status (SES). The reason for this is that only 10% of the mothers in the lowest SES were able to provide good pro-

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[10] Measures of mother–infant interaction consisted of ratings by trained staff based on interviews and observations conducted in the home. Examples of independently coded problem behaviors include the following: hyperactivity, temper tantrums, overdependence, timidity, and negativism. See original source for further details.

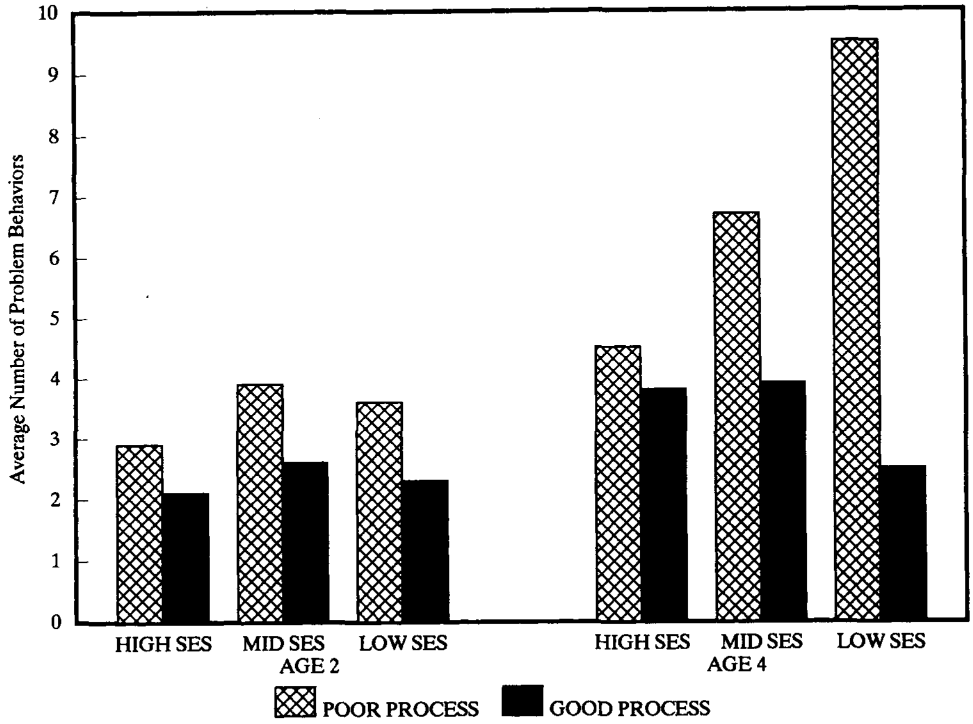

Figure 1. Effects of proximal process at age 2 on children's problem behaviors at ages 2 and 4 by social class (SES = socioeconomic status).

cess as compared with 60% in the highest SES group.[11] Moreover, from the perspective of an ecological model, there is both argument and evidence to suggest that the greater developmental impact of proximal processes in poorer environments is to be expected only for indexes of developmental dysfunction (e.g., problems in emotional control, psychological dependency, social disruptiveness, or other behavior patterns subsumed under the general heading of behavior disorders[12]). For outcomes reflecting developmental competence (e.g., mental ability, academic achievement, or practical and social skills),[13] proximal processes are posited as having greater impact in more advantaged and stable environments throughout the life course.

The theoretical basis for this differential set of expectations arises from the following six assumptions underlying the bioecological model:

1. Proximal processes not only actualize genetic potentials but, in the course of doing so, they also give such potentials substantive content through interaction with the external environment.

2. Not all of the genotypic possibilities that a given child possesses find realization in phenotypic form. The nature of the emergent phenotypes will depend on the activities that take place in the principal proximal settings in which the child is growing up. These activities, in turn, depend for their content on the characteristics of the persons, objects, and symbols present in the immediate environment. In sum, only those genetic predispositions of the individual can find realization for which the necessary *opportunity structures* exist, or are provided, in the particular immediate settings in which that person lives. Thus proclivities for acquiring a foreign language, mastering a musical instrument, or debugging a computer program require for their realization the presence of opportunity structures (e.g., friends or relatives who speak another language, music teachers, or computer manuals).

3. As specified by the bioecological model, some aspects of the immediate setting become partially transformed through the child's capacity to shape his or her own environment. However, early in life, such capacities are still limited in scope; they produce appreciable effects only in a restricted segment of the environment; namely, they influence the reactions of parents and other caregivers to behaviors of the infant that reflect its

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[11] There is, of course, the possibility that the 10% figure could be raised through experimental intervention of the type used by Riksen-Walraven with her sample of working class families.

[12] The term *dysfunction* as used in this context excludes diagnosable severe psychopathology, such as schizophrenia, clinically significant depression, infantile autism, or pronounced organic deficits. However, to the extent that persons with these conditions are responsive to their environment, we would expect the implications suggested by the bioecological model to apply to these conditions too.

[13] Some may argue that we are creating a false dichotomy, because competence and dysfunction simply represent opposite ends of the same continuum. The issue, however, is one of construct validity (Cronbach & Meehl, 1955) that can only be resolved empirically. For instance, if it can be shown that competence and dysfunction have different developmental antecedents (as evidenced in the two studies here described), then the assumption that they are points on a single continuum is no longer tenable.

own emotional state and dispositional tendencies. By contrast, the range of possibilities for changing the immediate environment by parents is much greater. Not only can they respond to the infant's cues and initiatives but they can also engage the child in new kinds of activities involving interaction not only with themselves and others but also with objects, toys, symbols, and other stimuli that can become the focus of proximal processes in their own right without necessarily involving other persons. Once again referring back to Proposition 2, this is the first and most direct way in which the content of proximal processes is provided by the environment, that is, the way in which parents and other adults determine the kinds of proximal processes in which their children do, or do not, become engaged.

4. However, there is another, more indirect way as well. For parents to further their children's learning and skill typically requires knowledge, know-how, and materials that, at some point, originated in the external world and, in effect, had to be imported into the family from the outside. Families who live in environmental contexts that contain such needed resources are therefore placed at an advantage in that the proximal processes taking place in the immediate setting can, as it were, deliver the needed goods (Kohn, 1977; Kohn & Schooler, 1983; Kohn & Slomczynski, 1990). By contrast, for families in disadvantaged environments, the same level of proximal process cannot yield the same return. For example, parents with limited education may not have the knowledge or skill to help the child with his homework in math.

5. Resources are not the only features of the environment that are required for proximal processes to operate successfully. A second essential is some degree of stability. Proposition 1 stipulates that to be effective the proximal processes driving development "must occur on a fairly regular basis over extended periods of time." In this regard, a growing body of evidence documents the disruptive developmental effect of unstable environments, characterized by inconsistent and unpredictable patterns of activities and relationships in the immediate settings in which the developing person lives, particularly within the family. For example, many stepparent families appear to be characterized by a lack of parental consistency and clarity of roles (Hetherington & Clingempeel, 1992; Pasley & Tallman, 1987; Zimiles & Lee, 1991). Moreover, the ultimate sources of such instability are often stressful conditions originating in domains outside the family, such as the world of work, the neighborhood, or the society at large. Under such circumstances, the power of proximal processes to enhance effective psychological development can be significantly undermined.

Perhaps the most comprehensive evidence for such an effect comes from a longitudinal study conducted by the Finnish psychologist, Pulkkinen (1982, 1983; Pulkkinen & Saastamoinen, 1986). The investigator and her colleagues examined the influence of environmental stability and change on development of children between 8 and 20 years of age. Experience of instability over time (e.g., changes in family structure, daycare and school arrangements, or parental employment; the number of family moves; and the frequency of parental absence) was associated with greater insecurity later in life, as well as a higher incidence of problem behaviors such as submissiveness, aggression, early sexual activity, excessive smoking, drinking, and delinquency. These effects could be found within as well as between social classes but exerted a greater influence on developmental outcomes than did socioeconomic status.

Subsequent research has provided more specific evidence that stress and inconsistency within the family have disruptive effects on children's development, both for outcomes of developmental dysfunction and of cognitive competence. For example, the degree of conflict versus harmony in the marriage influences patterns of parent–child interaction (Belsky & Rovine, 1990), which in turn affects children's school achievement and social behavior in the classroom (Cowan, Cowan, Schulz, & Heming, 1994). At the same time, the quality of the marital relationship has itself been shown to be powerfully affected by extra-familial factors such as conditions at work (Bolger, DeLongis, Kessler, & Wethington, 1989; Eckenrode & Gore, 1990; Moorehouse, 1991).

Indeed, it is environmental conditions and events originating outside the family that are likely to be the most powerful and pervasive disrupters of family processes affecting human development throughout the life course. Perhaps the most compelling evidence on this score is found in the longitudinal studies conducted by Glen Elder and his colleagues on the short- and long-range developmental consequences, both for children and adults, of direct involvement in such historical events as the Great Depression of the 1930s (Elder, 1974, 1986; Elder, Caspi, & Van Nguyen, 1986), World War II and the Korean War (Elder, 1986, 1987), or the loss of the family farm during the 1980s (Conger et al., 1992; Conger & Elder, 1994; Elder, Conger, Foster, & Ardelt, 1992).

In short, environmental contexts influence proximal processes and developmental outcomes not only in terms of the resources that they make available, but also in terms of the degree to which they provide the stability and consistency over time that proximal processes require for their effective functioning.

6. Proximal processes not only require environmental stability for their effective functioning but they also engender psychological stability in others, particularly in children and youth. It seems probable, though still to be systematically demonstrated on a broad scale, that most parents possess the capacity for some effective response to their children's distress and disturbed behavior even when resources from the external environment are in short supply. The already cited results of Drillien's research are a case in point. Along the same line, studies of the effects of malnutrition on children's early psychological development indicate that mother–infant interaction exerts an important buffering effect (Ricciuti, 1991; Wachs et al., 1992). In a similar vein, Cohen, Parmelee, Sigman, and Beckwith (1982) found that caregivers tend to be more responsive to infants who experience serious illness or developmental delay. At the same time, there is evidence that the severity of developmental dysfunction is markedly increased for families living in disadvantaged and unstable environments.[14] Hence, to the extent that families can manage to respond appropriately to their children's

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[14] For example, in Drillien's data, the percentage of children exhibiting one or more problem behaviors was 80% in the lowest social class group compared with 44% in the highest. As noted earlier, the average number of problem behaviors was twice as high in the former group as in the latter (8 and 4, respectively).

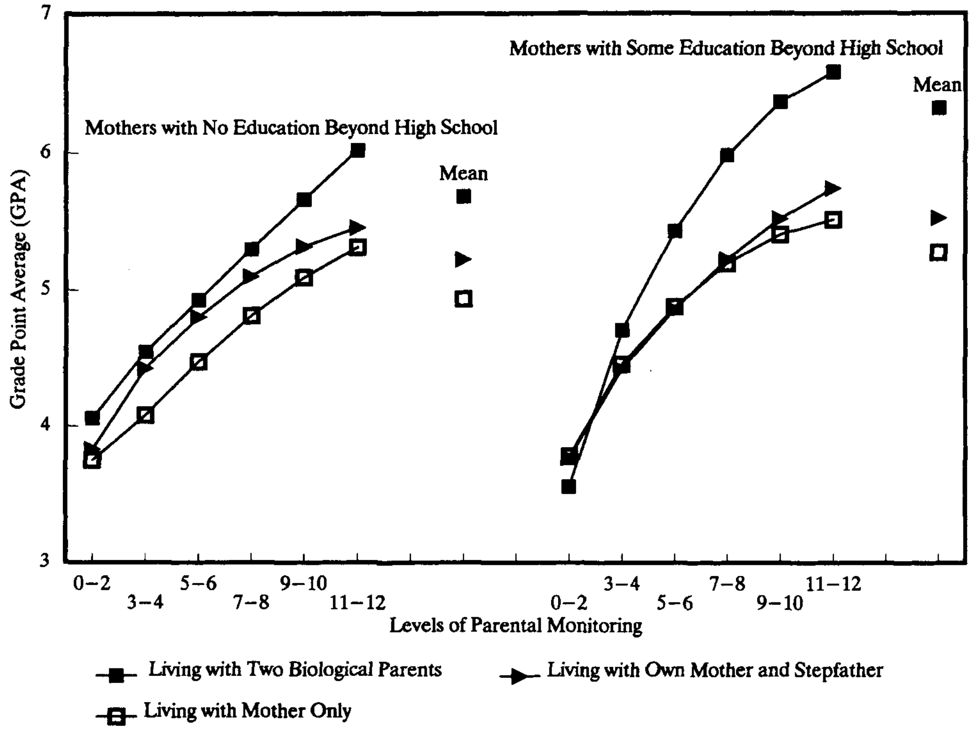

Figure 2. Effect of parental monitoring on grades in high school by family structure and mother's level of education. Means represent mean grade point averages for each group. GPA scale: 2 = mostly Ds or less; 3 = one half are Cs, and one half are Ds; 4 = mostly Cs; 5 = one half are Bs, and one half are Cs; 6 = mostly Bs; 7 = one half are As, and one half are Bs; 8 = mostly As.

dysfunctional states and behaviors, the buffering effect turns out to be substantial.

Taken together, the foregoing considerations lead to the expectation that, in contrast to the pattern observed for measures of developmental dysfunction (e.g., problem behaviors in Drillien's study), the effect of proximal processes on outcomes reflecting functional competence will be stronger in advantaged and stable environments than in those that are impoverished or disorganized. The next research example illustrates this phenomenon.

Example 3: Proximal Process and Adolescents' School Achievement

Figure 2 depicts the differential effects of parental monitoring on school achievement for high school students living in the three most common family structures found in the total sample of over 4,000 cases.[15] The sample is further stratified by two levels of mother's education, with completion of high school as the dividing point. Parental monitoring refers to the effort by parents to keep informed about and set limits on their children's activities outside the home. In our study, we assessed this with a questionnaire administered to adolescents in their school classes. Levels of parental monitoring, ranging from 0 to 12, are shown on the horizontal axis, grade point average (GPA) on the vertical. The markers to the right of each curve record the mean GPA for each of the six groups.

Once again, the results reveal that the effects of proximal processes are more powerful than those of the environmental contexts in which they occur. In this instance, however, the impact of the proximal process is greatest in what emerges as the most advantaged ecological niche: families with two biological parents in which the mother has had some education beyond high school. The findings of this analysis differ from those of the preceding example in yet another respect. In the Drillien study, not only were the effects of proximal processes on individual differences greater in the more disadvantaged environment but these processes also substantially reduced group differences associated with social class, especially for children experiencing a poor process. In Figure 2, one can see the very opposite pattern. At the lowest level of monitoring, differences by social class and family structure are minimal but rise markedly as monitoring increases.

One other feature in Figure 2 is worthy of note. The typically declining slope of the curve reflects the fact that higher levels of outcome are more difficult to achieve so that at each successive step, the same degree of active effort yields a somewhat smaller result. Thus, in this case, for pupils who are not doing so well in school, parental monitoring can apparently accomplish a great

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[15] The data on which the analysis shown in Figure 2 was based were generously provided by Steven Small and Thomas Luster from their statewide studies of youth at risk in Wisconsin (Small & Luster, 1990).

deal by ensuring stability of time and place so that some learning can occur. Superior school achievement would clearly also require high levels of motivation, focused attention, previous knowledge, and—especially—actually working with the material to be learned, all qualities that stability of time and place by itself cannot provide. Consistent with this interpretation, the sharpest declines in slope are seen in those environments that contain the substantive resources, over and above situational stability, needed for a higher level of achievement.

We are now in a position to formulate a second hypothesis, one that stipulates how the effects of proximal processes will vary as a joint function of characteristics of the environment and the nature of the developmental outcome under consideration. The complexity of the phenomena with which the hypothesis deals is reflected in its hierarchical structure; its initial postulate is followed by two lemmas.

> *Hypothesis 2:* Proximal processes actualize genetic potentials both for enhancing functional competence and for reducing degrees of dysfunction. Operationally, this means that as the level of proximal process is increased, indexes of competence will rise, those of dysfunction will fall, and the value of h^2 will become greater in both instances.
>
> 1. The power of proximal processes to actualize genetic potentials for developmental competence (as assessed by an increase in h^2) will be greater in advantaged and stable environments than in those that are disadvantaged and disorganized.
>
> 2. The power of proximal processes to buffer genetic potentials for developmental dysfunction will be greater in disadvantaged and disorganized environments than in those that are advantaged and stable.

Having provided examples of research findings in support of Stage 1 of Hypothesis 2, we turn to the specification of a research design that would permit the testing of Stage 2. As before, this involves including groups of contrasting consanguinity in the sample and then computing heritability coefficients for each of the ecological niches in the study design.

In the case of the Drillien study (Figure 1), there are six such niches (2 Levels of Proximal Process × 3 Levels of Social Class). In the case of the monitoring research (Figure 2), the proximal process was measured as a continuous variable. Because heritability is calculated on a group basis, it is necessary to stratify the monitoring score into at least two successive levels. Under these circumstances, the total number of ecological niches would be 12 (2 Levels of Proximal Process × 3 Forms of Family Structure × 2 Levels of Education).[16]

For Hypothesis 2 to be sustained with respect to the Drillien study (Figure 1), the following pattern of results would be required:

1. Within each social class group, higher levels of mother–infant interaction (i.e., good process as compared with poor process) should lead to reduced problem behavior and higher levels of heritability.

2. These effects should be most pronounced in the lowest social class; that is, the differences associated with levels of proximal process both in problem behavior and heritability are expected to be greatest in the most disadvantaged environment.

By contrast, in the monitoring study (Figure 2), although the general effects of the proximal process should be the same, the pattern of environmental differences should be reversed. Specifically:

1. For each form of family structure at both levels of mother's education, higher levels of monitoring should be associated with both better school achievement and greater heritability.

2. The greatest differences both in school performance and in heritability associated with high versus low levels of monitoring (i.e., the power of the proximal process) will be found for children of two biological parents living together in advantaged environments; the smallest differences will be found for single-parent families living under straitened circumstances.

As previously mentioned, we have been able to find no studies of genetic inheritance in contrasting environments that also contained data on proximal processes and hence would permit a direct test of this aspect of the hypothesis. It is possible, however, to carry out an indirect, and admittedly weaker, test in the absence of actual data on proximal processes. The test is based on the following line of reasoning: There is now an appreciable body of evidence indicating that what we have called proximal processes tend to occur at higher levels of magnitude in more advantaged and more stable environments.[17] Given such findings, it would follow, if the bioecological model is valid, that levels of heritability should be consistently higher in more advantaged and stable environments.[18]

This indirect test can be carried out only when estimates of heritability are reported for the same developmental outcome in different environments. It is fortunate that there are several studies that meet this criterion. To begin with, both Scarr-Salapatek (1971) and Fischbein (1980) found support for the prediction that values of h^2 for IQ would be greater in higher than in lower social class groups. Subsequently, a group of Norwegian investigators (Sundet, Tambs, Magnus, & Berg, 1988) undertook to clarify a series of earlier findings regarding secular trends over recent decades in heritability for measures of cognitive functioning. Using IQ scores as outcome data, the investigators found some support for results of a previous study of educational attainment (Heath et al., 1985) that had shown an increase in h^2 for twins born after 1940. The trend for their own mental test data, however, was considerably weaker. The authors offered the following interpretation of the observed similarity and contrast:

> This is probably due at least partly to the fact that the Norwegian government in the postwar period has offered loans to young people seeking education, thus enabling youngsters with poor parents to attend higher education. Such factors, together with a more positive

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[16] Once again, the problem arises of ensuring a sufficient number of cases in each cell of the matrix. With a total sample size of more than 4,000, this may still be possible. If not, the analysis could be confined to the two forms of family structure that are most frequent in the sample, or to the larger of the two social classes.

[17] For reviews of relevant studies, see Bronfenbrenner (1986, 1989a, 1993, 1994). In addition, in the last example, not only was the average level of parental monitoring higher for children of mothers with more education but, within each educational group, adolescents living with their own parents were monitored most, and those with a single-parent mother least, with this difference being more pronounced at the higher educational level.

[18] In the light of Propositions 1 and 2, this effect would not be expected to be as large as that associated with contrasting levels of proximal process within each environment.

> attitude towards education among poor people, would tend to decrease the effect of familial environments and maximize genetic potential. (Sundet et al., p. 58)[19]

If one views education as involving some proximal processes, these findings provide indirect support for Hypothesis 2 (including the possible effect of changing belief systems on levels of heritability).

There are also a number of investigations that permit an indirect test of the hypothesized reverse pattern when the outcome is one of developmental dysfunction. For example, Jenkins and Smith (1990) found that the positive effect of a good mother–child relationship on children's problem behavior was stronger in a troubled marriage than in a harmonious one. More generally, in a recent review, Rutter and Rutter (1992) concluded that the impact of protective factors in buffering developmental disorders is greater in "circumstances of risk" (p. 56).

Given its complexity, Hypothesis 2 poses an even more stringent test of the bioecological model than does its predecessor,[20] a consideration that also applies to the hypothesis that follows.

Experimental Intervention and Heritability

Our very first example, Riksen-Walraven's intervention experiment, indicated that intervention programs that focus on enhancing proximal processes can lead to higher levels of developmental functioning. However, if Hypothesis 2 is valid, it has some unwelcome implications for the success of such programs; namely, these programs will be least successful in actualizing genetic potential for developmental competence in those groups who need it most: children and youth growing up in the most disadvantaged and stressful environments.

However, from the perspective of a bioecological model, there are both theoretical and empirical grounds for expecting that this may not be the case. In fact, the very reverse may be true; contrary to Hypothesis 2, intervention programs that enhance proximal processes may be most effective in the poorest and most disorganized environments. This paradoxical expectation is based on the following considerations.

By definition, an experimental intervention exposes participants to resources and experiences not available in the everyday settings of their lives. In effect, what is happening in such instances is that the second setting is exporting needed resources of knowledge and skill into the first—a situation that would seem to be analogous to that of middle-class families, for whom the external milieu provides the same kinds of needed resources (see earlier). However, there is also an important difference. Children and adults in middle-class households have usually had access to such resources for most of their lives, whereas those growing up in straitened circumstances typically have not. Providing an intervention program for the latter group creates what, in ecological terms, is referred to as a mesosystem, a situation in which the same person is participating in more than one setting (Bronfenbrenner, 1979, 1994). In this instance, the additional external setting (i.e., the intervention staff together with their special knowledge and know-how) provides the participants in the program with resources that are not available in the other settings of their lives. This same contrast can also arise in natural circumstances, for example, when children living in a disadvantaged neighborhood attend an exceptionally good school. A telling research example of this phenomenon in young adulthood appears in Elder's follow-up studies of children of the Great Depression of the 1930s (Elder, 1986, 1987). Sons from families that were hardest hit economically were most likely to enter military service at the earliest possible time and to benefit from the experience in terms of their subsequent development. Compared with nonveterans, they had more stable marriages and "showed a larger gain in psychological strength" (Elder, 1986, p. 233).

The foregoing considerations lead to a third and final hypothesis that, if validated, has significant implications not only for science but also for society.

> *Hypothesis 3:* If persons are exposed over extended periods of time to settings that provide developmental resources and encourage engagement in proximal processes to a degree not experienced in the other settings in their lives, then the power of proximal processes to actualize genetic potentials for developmental competence will be greater for those living in more disadvantaged and disorganized environments.

The rationale for this hypothesis is perhaps best conveyed by a corresponding hypothetical example from a related but different substantive domain—that of human nutrition. Consider family groups living in two different kinds of environments, one in which sources of food are in short supply, in the other quite plentiful. Now suppose that, over a period of time, the same modest levels of supplementary nutrients are regularly provided to both groups and are consumed in comparable amounts. Under these circumstances, one would expect the greatest increase in weight, with correspondingly higher levels of individual differences in actualized genetic potential (h^2) in the more deprived environment.

Translated into the psychological realm, the rationale is similar to that for Hypothesis 2, despite the difference in predicted outcome. There we argued that, because most parents possess the capacity for some effective response to a child's distress, to the extent that parents respond appropriately the buffering effect against dysfunctional outcomes will be greater in more impoverished and unstable environments. With respect to outcomes of developmental competence, however, lower class par-

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[19] Recently, Sundet (personal communication, March 17, 1993) reported that, in response to a preliminary version of this article, he and his colleagues undertook a preliminary analysis that yielded the following results: "For twins with mothers having the least education, the correlation between identical twins is .80, whereas the correlation for fraternal twins is .47. For the twins having mothers with more education, these correlations are .82 and .39, respectively. As you will see, this yields a heritability estimate of .66 for the first group, whereas it is .86 for the second group. If I understand your hypothesis correctly, this is in accordance with your predictions. However, the difference between the two DZ [dizygotic] correlations does not seem to reach statistical significance, although it is quite near."

[20] We are grateful to an anonymous reviewer for pointing out that if Hypothesis 2 were sustained, it would also contradict predictions based on the established behavioral genetics model. The hypothesis posits that the effect of proximal processes on heritability will differ in advantaged versus disadvantaged environments. The reviewer wrote, "This hypothesis is in contrast to the undifferentiated current behavioral genetics hypotheses that if environment is held constant at any level of genetic risk, genetic variance will be maximized."

ents do not have access to the needed resources. However, if these resources are provided by some other setting, then, in a general climate of scarcity, the developmental impact of such resources is even greater than it would be in an environment in which needed resources are readily available. In sum, in actualizing genetic potentials for psychological development, needed resources and skills provided by an external setting will have their greatest impact where they are in shortest supply.

The Ecological Model: An Integrated View

Having described and discussed the principal components of the bioecological model, we are now both able and obligated to put the pieces together in an effort to depict the complex system as a whole. The result of that effort appears in Figure 3.

Viewed from the bottom upward, Figure 3 traces the hypothesized biosocial trajectory through which genotypes are transformed into phenotypes. That trajectory receives both its impetus and early direction from the genetic endowment inherited from the child's biological parents, but from the very outset it is proximal processes that serve as the mechanisms for the actualization of genetic potential. It is reasonable to assume that such processes acquire their psychological content through a dynamic fusion between genetically driven patterns of selective attention, action, and differential response, on the one hand, and, on the other, the nature of the environments through which the organism passes on its life journey. Finally, it is this fusion that determines which genetic potentials for competence or dysfunction ultimately find realization.

Figure 3 also provides a convenient basis for summarizing the ways in which the bioecological model goes beyond and differs from the classical behavior–genetics paradigm. First and foremost, it stipulates proximal processes as the mechanisms through which genetic potentials are actualized, hence the increase in heritability (h^2) as proximal processes rise. Second, such mechanisms are posited as exerting a relatively more powerful effect on development than do the environments in which they operate. Accordingly, the differences in developmental outcome (and corresponding levels of h^2) between poor versus good environments are consistently smaller than those associated with low versus high levels of proximal process. Third, because in this instance the outcome is one of developmental competence, the impact of proximal processes both on the level of the outcome and its heritability is greater in good environments than in poor ones (Hypothesis 2). Witness the greater distance between the two platforms on the right side of Figure 3 as compared with those on the left.[21] Finally, the central vertical arrow in Figure 3 is broken rather than solid to emphasize a core principle underlying the bioecological model, namely, that the influence of genetics and environment on human development are never wholly separable but an ever-evolving amalgam. On the one hand, as we have indicated at the very outset of this exposition, genetic potentials are not preformed but, rather, are capable of alternative expression. Thus, from the moment of conception, the actualization of inherited predispositions for embryological development and physiological activity do not occur in a vacuum but are differentially responsive, in this instance, to the intrauterine environment. On the other hand, the power of innate propensities is in no way reduced after birth, for, as the child begins to interact with persons, objects, and symbols, the external environment becomes genetically loaded as the active organism selects, modifies, and partially constructs its own world.

In sum, the traditional wisdom embodied in the phrase "Nature proposes, environment disposes" is in need of some emendation, for both the proposing and the disposing are jointly determined. It is no more correct to say that one factor solely proposes than the other. "Even if we knew the complete DNA [deoxyribonucleic acid] sequence of an organism, we could not reconstruct its morphology. We need to know about the epigenetic interactions that generate the phenotype" (Albersch, 1983, p. 862). The bioecological model represents a restatement and extension of this cogent principle beyond the domain of morphology into the sphere of psychological development.

The Challenge of Unanswered Questions

Having sought to make the best possible case for the bioecological model, we also readily acknowledge that the case is incomplete, in terms of both evidence and argument. First and foremost, the most critical elements of the model—those on which it either stands or falls—although testable, have yet to be tested.

We referred to Stage 2 of each hypothesis, which stipulates an effect of proximal process on heritability. Despite an intensive search, we have not been able to find published or unpublished data that would permit a direct test of this key component. Hence, in our view, the collection of such data, and their analysis within the framework of a bioecological model, presents a promising prospect for future research.

The second stage of the model is also incomplete with respect to a *terra incognita* that it shares with the classical behavioral genetics paradigm; namely, neither model addresses, either conceptually or empirically, the question of group as opposed to individual differences in actualized genetic potential. To be sure, through the use of experimental strategies it is possible to demonstrate the independent effect of proximal processes on differences between groups both in developmental outcome and in the degree to which variation within each group is attributable to actualized genetic potential as reflected in h^2. Nevertheless, neither model can estimate the extent to which differences in developmental outcome between groups, whether observed in society or produced experimentally, reflect differences in realized innate potential. In short, we have no way to calculate a between-groups analogue for h^2. Once again, the issue cannot be resolved solely on the basis of phenotypic data and must wait on the development of biogenetic methods for assessing human genotypes.

Important gaps in knowledge also exist with respect to the first stage of our key hypotheses. To begin with, there is reason to expect different kinds of proximal processes to vary in their

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[21] In the case of an outcome reflecting developmental dysfunction, the distance between the two platforms would be greater on the left rather than the right side of Figure 3. This reversal in pattern is in accord with Hypothesis 2, which stipulates that, for dysfunctional outcomes, the impact of proximal processes (and the corresponding increase in h^2) is greater in disadvantaged and unstable environments.

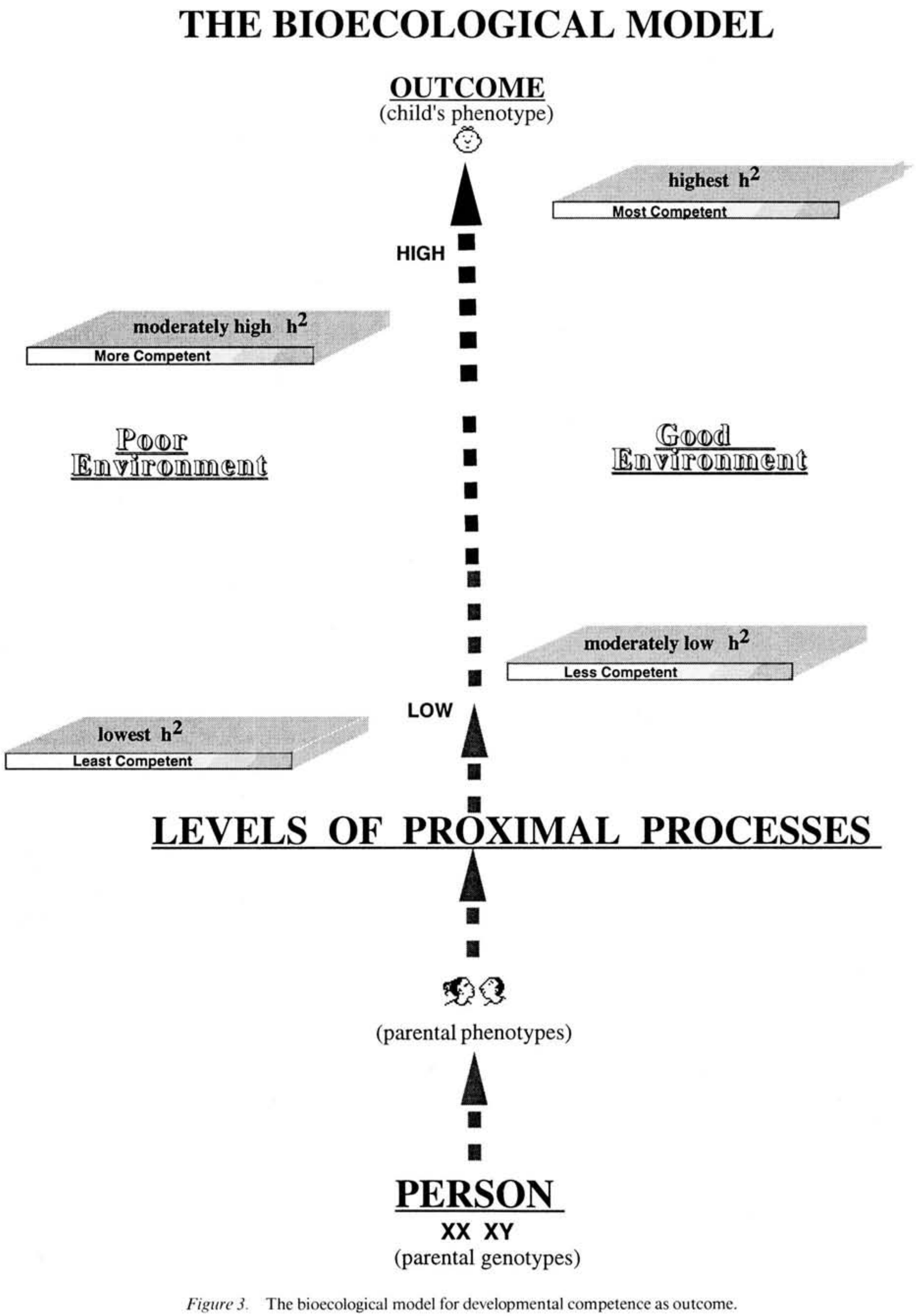

Figure 3. The bioecological model for developmental competence as outcome.

developmental power, some being more effective than others. One may speculate that such effectiveness increases as a function of the degree of reciprocity that the process allows (Sameroff & Chandler, 1975). We have been able to find only one study that sheds some light on this possibility. It is regrettable that none of the behaviors assessed involve high levels of two-way interaction. Fischbein and her colleagues (Fischbein, Gutman, Nathan, & Eraschi, 1990) compared samples of twins exposed to permissive versus restrictive educational environments both in Sweden and in Israel. Preliminary findings indicated that "logical abstract thinking as well as reading and mathematics achievement seem to be less influenced by hereditary factors in a restrictive educational setting than in a permissive one" (p. 246).[22]

Note that, from the perspective of a bioecological model, what was in effect being investigated in this study was one half of what we have called a proximal process; namely, children were exposed to situations in which they were either free or not free to be responsive to their environments, but no provision was made for contrasts in the degree to which the environment, in turn, was responsive to the behavior of the children. On the assumption that two-way processes of interaction are more likely to occur in a permissive than in a restrictive environment, the results of this study suggest that levels of actualized potential for cognitive competence would be even higher in classrooms that actively encouraged reciprocal activities involving both teachers and students.

Furthermore, it remains to be shown that the results obtained in this study are not specific to the particular processes and ages under consideration. Moreover, the definition of proximal process presented in Proposition 1 goes beyond interaction between persons to encompass activities with objects and symbols as well. Although there are some investigations in which such activities have been assessed as developmental outcomes (e.g., analyses of individual differences in children's solo play activities), we have yet to find studies in which such behaviors are analyzed as mechanisms driving further developmental growth.

However, if our assumptions about the power of such mechanisms are valid, then even more promising possibilities arise from the fact that, to date, existing studies of proximal processes have focused on only one process at a time (e.g., mother–infant interaction or parental monitoring). Yet, basic to the bioecological model is the principle that its elements combine in nonadditive, synergistic fashion. If this principle in fact holds, it points to the importance of using research designs that permit the assessment of the joint synergistic effects of two or more processes involving different agents and activities (e.g., solo as well as joint activities, fathers as well as mothers, peers as well as adults, and activities at school as well as at home). Under such circumstances, the magnitude of observed h^2s should be even greater.

Nevertheless, despite the greater power that such further elaborations in design may provide, there remain large domains of human genetic potential that the bioecological model by definition entirely excludes from its scope. For example, of the range of personality traits that human beings exhibit, very few can be easily categorized into a dichotomy of developmental competence versus dysfunction. On closer inspection, even that *dichotomy itself* turns out to be incomplete and asymmetrical in its structure. The nature of the gap and the asymmetry become apparent once each of these spheres is examined in terms of its operational definition, the corresponding h^2.

The meaning of h^2 in the first instance is quite straightforward: It indicates the proportion of observed variance attributable to expressed genetic potential for developmental competence. The interpretation of the second h^2 takes a somewhat different form. If it is true, as we are proposing, that the value of h^2 is maximized at higher levels of proximal process, then, strictly speaking, what h^2 estimates in this instance is the proportion of observed variance attributable to actualized genetic potential not for expressing dysfunctional outcomes but for buffering against and thus reducing them.

If so, this raises the provocative question of whether it is possible to assess individual differences in actualized potential—not for buffering against dysfunctional outcomes but for their direct expression. If so, what are the mechanisms through which such actualization occurs? At this point, all we can offer in response are speculations. To start with the second part of the question, we have defined proximal processes in terms of "progressively more complex reciprocal interaction with persons, objects, and symbols in the immediate environment." However, suppose these environmental features are not responsive to the behavior of the developing person, that is, they remain rigid or react in unpredictable fashion. Suppose, in particular, that parents or other principal caregivers in the child's life are inattentive or act in ways that are unrelated to the child's state and behavior, for example, they are inconsistent, explosive, or excessively withdrawn. At the extremes, there is the possibility, and all-too-often the reality, of deliberate rejection or abuse. Under these circumstances, the child, being genetically endowed with dynamic dispositions for action, usually still continues to interact with the immediate environment but the responses that he or she may evoke are neither reciprocal nor progressively more complex. Such patterns of nonresponsive, developmentally disruptive interaction may serve as the mechanisms through which genetic potentials for developmental dysfunction are actualized. In contrast, what we have called proximal processes reflect the operation of such disruptive mechanisms only by default. Is it possible that if the latter were to be measured directly, they would turn out to predict differences in h^2 that are positively rather than negatively correlated with the expression of dysfunctional outcomes?

Finally, in addition to the foregoing, as yet unanswered questions, there is also a long-accepted answer that can now be seriously questioned. We present it within the established behavioral genetics framework from which it stems. It is a fact that most h^2s computed on tests of mental ability exceed .50 and often run as high as .80 (see Ceci, 1990; Pedersen, Plomin, Nesselroade, & McClearn, 1992). Does this not mean that most of

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[22] Independent support for the same generalization at an earlier age appears in an analysis reported by Plomin, DeFries, and McClearn (1990). Results from a study of mental development among natural versus adopted children followed over the first 2 years of life suggested that "genetic differences emerge more clearly in less constrained environments—a hypothesis that has been proposed on the basis of genotype-environment interaction research within mice (Henderson, 1970)" (Plomin, DeFries, & Fulker, 1988, p. 233).

the genetic potential for intelligence is already being actualized so that our claims about the promise of proximal processes for increasing levels of intellectual functioning are somewhat academic? As we have indicated earlier, this line of reasoning can be called into doubt on two grounds. First, science has not yet found a way to measure the total genetic potential of human beings, either at the level of individuals or of groups. At present, all that can be estimated is the proportion of observed variation in individual differences that can be attributed only to actualized genetic potential.

However, even granting this qualification, does it not follow that an h^2 of .80 for IQ means that 80% of the observed variation in intelligence is attributable to genetic endowment, with only 20% at most that could be accounted for by environmental influences?[23] This is one of the crucial points at which the traditional and the bioecological models part company, for the latter has as its cornerstone the thesis that actualized genetic potential involves substantial environmental components. Hence h^2 cannot be interpreted as an estimate of the proportion of variance in a given developmental outcome that is completely free of environmental influence. On the contrary, environmental factors are seen as playing a major role in determining which individual capacities are realized and to what extent.

To be more specific, allowing for the indisputable fact that certain psychological characteristics are more strongly influenced by genetic inheritance than are others, which innate potentials become manifested in phenotypic form depends on whether the environments in which the human beings are living allow and instigate the actualization of particular inherited abilities and behavioral dispositions. The key factor is whether, in a particular family, school, community, workplace, culture, or place and period in history, the outcome in question is given salience in the beliefs and the behaviors of both self and others in each of these environmental contexts. In short, which features of the environment become, or are made, salient plays a critical role in determining which of a multitude of innate possibilities have the most chance of finding realization.

The scope and power of such environmental conditions and events have perhaps been best expressed in the words of one of the leading human geneticists of our time, Theodore Dobzhansky (1955). He put it this way:

> The norm of reaction[24] is at best only incompletely known. Complete knowledge of a norm of reaction would require placing carriers of a given genotype in all possible environments, and observing the phenotypes that develop. This is a practical impossibility. The existing variety of environments is immense, and new environments are constantly produced. Invention of a new drug, a new diet, a new type of housing, a new educational system, a new political regime introduces new environments. (pp. 74–75)

More recently, Lloyd Humphreys (1991), a leading researcher in the field of human abilities, has, in effect, restated Dobzhansky's norm of reaction in terms of its implications for society and social policy:

> Because environmental variance can be more readily and effectively manipulated by social policies, it would be a tribute to our democratic society if the heritability in the American population today were as high as .8. Most informed persons place the ratio substantially lower.
>
> Some behavior geneticists speculate that heritability may be lower today than a generation ago. If so, persons holding democratic values have no reason to rejoice. If true, by far the more probable cause is increasing rigidity of the class structure that is producing larger amounts of environmental variance. . . . A society can deal effectively and democratically with genetic contributions to individual differences in abilities and temperament with policies designed to maximize the achievement of each citizen without regard to sex, race, ethnicity, or social status. This requires a focus on equality of opportunity. This goal with this focus is equivalent to the goal of maximizing heritability of the human qualities that produce high levels of achievement. (p. 343)

Humphreys's last sentence is especially critical, for, as we have illustrated, it is also possible to maximize the heritability of human qualities that produce low levels of human achievement.

To attain Humphreys's stated goal, it is necessary to identify the specific psychological processes and conditions that transform genotypes into phenotypes. Although much has been accomplished over a short period in the comparatively new discipline of molecular genetics (Plomin, 1993; Plomin & Rende, 1991), those "specific processes and conditions" are still to be discovered. The present theoretical contribution, together with suggested research designs and related empirical evidence, represents an effort to provide a new forward base for further scientific exploration in this uncharted domain.

Recapitulation and Coda

Although some of the research questions generated by the model we have presented raise issues that are not yet scientifically resolvable, there are others—those constituting the basic elements of the model—that are directly susceptible to empirical test. These are concretized in the three hypotheses we have proposed for systematic investigation. Each of these hypotheses focuses on what we regard as the most important potential contribution of the proposed model, namely, a possible answer to Anastasi's question, "How?" What is the nature of the mechanisms that transform phenotypes into genotypes?

Should our hypotheses turn out to have some validity, this would have implications both for science and for social policy. In the former domain, they could provide a beginning insight into the processes of genetics–environment interaction that shape human development. In the latter sphere, confirmatory results would suggest that many human beings may possess innate potentials for development significantly beyond those that they are presently manifesting, and that such unrealized capacities might be actualized through social policies and programs that enhance exposure to proximal processes in environmental settings that, in turn, can provide the stability and resources that enable such processes to be most effective.

At this time, such policies and programs take on new importance. Thus, there is evidence that the social changes that have been taking place over the past 2 decades in developed as well as developing societies have undermined conditions necessary for healthy psychological development (Bronfenbrenner, 1958, 1985, 1989b, 1992). Hence, if shown to be valid, the proposed

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[23] In the established behavior genetics model, the percentage would be even less because the 20% also includes measurement error.

[24] The term refers to all phenotypic outcomes of a single genotype exposed to all possible environments.

model provides a basis for designing more effective strategies for counteracting this downward trend through the provision of environments in which proximal processes can be enhanced.

However, thus far, it has by no means been demonstrated that the hypotheses we have set forth are indeed valid; nor is such demonstration the main purpose of this undertaking. Indeed, our aim, and that of developmental science as well, might be better served if the hypotheses were to be found wanting. Our principal intent has not been to claim answers but to construct a theoretical framework that might enable our colleagues in the field, and ourselves, to make some further progress in discovering the processes and conditions that define the scope and limits of human development and to provide a corresponding operational model that permits our theoretical position to be falsified. At the center of that framework is the thesis that what we have called proximal processes constitute the basic mechanisms that produce effective developmental functioning. However, that is not the whole story. To invoke and extend an earlier metaphor, if proximal processes are the engines of development, it is the characteristics of person and context that provide the needed fuel and do most of the steering. However, in the end, what matters most is the destination reached.

As Dobzhansky implied, we cannot define that destination in advance, but we can nevertheless aspire and strive to attain it. Over a decade ago, Bronfenbrenner (1979), after reviewing the then-available findings from research on human development conducted in different disciplines, wrote as follows:

> Species *Homo sapiens* appears to be unique in its capacity to adapt to, tolerate, and especially to create the ecologies in which it lives and grows. Seen in different contexts, human nature, which I had once thought of as a singular noun, turns out to be plural and pluralistic; for different environments produce discernible differences, not only across but within societies, in talent, temperament, human relations, and particularly in the ways in which each culture and subculture brings up the next generation. The process and product of making human beings human clearly varies by place and time. Viewed in historical as well as cross-cultural perspective, this diversity suggests the possibility of ecologies as yet untried that hold a potential for human natures yet unseen, perhaps possessed of a wiser blend of power and compassion than has thus far been manifested. (p. xiii)

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Received February 9, 1993
Revision received January 13, 1994
Accepted February 11, 1994 ■