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Nature, Nurture, and Development: From Evangelism through Science toward Policy and Practice

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During the second half of the 20th century there was an immense increase in both empirical findings on, and conceptual understanding of, the effects of nature, nurture, and developmental processes on psychological functioning—both normal and abnormal. Unfortunately, the good science has also been accompanied by excessive polarizing claims and by unwarranted extrapolations. This article provides a summary review of the real gains in knowledge, outlines some of the misleading claims, and notes the potential for research and for science-led improvements in policies and practice. The need to bring about a better interpretation of genetic, psychosocial, and developmental research strategies and theoretical concepts is emphasized.

INTRODUCTION

Over the last half century, there has been an explosion of knowledge on the effects of nature, nurture, and developmental processes. As a result, we have a much improved understanding of many of the mechanisms involved in normal and abnormal development, which carries with it a huge potential for improving children's lives. Unfortunately, these advances have been accompanied by as much misleading scientific evangelism and journalistic hype as by good science and honest reporting. As a consequence, both the pages of scientific journals and the media have been full of the most absurd confrontations and polarizations. These have given rise to an unhelpful level of misunderstanding of the true scientific advances and, more especially, about their meaning and the implications for policy and practice. Of course, there have also been numerous examples of good reporting by scientists and by journalists. There is every reason to be indebted to both. The need is to avoid the twin dangers of destructive cynicism and gullible expectation.

Nature, nurture, and development are dealt with in this article as separate topics (with the focus being mainly on their effects on psychopathology). In each case, the real advances in knowledge are considered first, some of the misleading claims are outlined second, and the potential for research and for improvements in policies and practice are noted third. Although these are considered as supposedly separate influences, the truth is that they are closely intertwined. The separation is heuristically useful for testing causal hypotheses, but it is crucial that such hypotheses deal with the different forms of interplay that may be occurring. To a considerable extent, it is the failure to do so that has led to many of the polarizing battles and absurd claims.

NATURE: GENETIC RISK AND PROTECTIVE MECHANISMS

With regard to the influences that reflect nature, quantitative genetics and molecular genetics are discussed separately, because they have rather different patterns of strengths and limitations.

Quantitative Genetics

Quantitative genetics uses various population designs (most particularly twin and adoptee studies) to quantify the relative strength of genetic and nongenetic factors with respect to population variance; that is, individual differences with respect to some trait or disorder (McGuffin & Rutter, in press; Rutter et al., 1990; Rutter, Silberg, O'Connor, & Simonoff, 1999a). Nongeneticists tend to assume that the only focus is on the heritability quotient, but that is not the case. The available techniques are able to partition genetic influences into those that are additive—that is, due to a mixture of many genes without there being any requirement for a particular pattern or combination—and those that are nonadditive—that is, reflect interactions among different genes (epistasis) or among different alleles of the same gene (dominance). Similarly, nongenetic influences can be subdivided into so-called shared and nonshared effects—those that tend to make siblings similar and those that tend to make

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them unalike, respectively. Gene–environment correlations and interactions may also be identified. Although traditional analyses have, in the past, tended to assume that genetic and nongenetic influences are entirely separable, there is no need to make that assumption. Quantitative genetic studies have increasingly tested for, and found, major interplay between genetic and non-genetic factors, such that the outcomes cannot sensibly be attributed to just one or the other, because they depend on both (Rutter & Silberg, in press).

Quantitative genetic designs rely on many assumptions, and it is crucial that these be put to the test in a rigorous fashion, making explicit just which are necessary (Rutter, Pickles, Murray, & Eaves, 2001; Rutter et al., 1999a). Critics have rightly pointed to problems, but any dispassionate reading of the evidence leads to the inescapable conclusion that genetic factors play a substantial role in the origins of individual differences with respect to all psychological traits, both normal and abnormal (McGuffin & Rutter, in press; Rutter, Silberg, O'Connor, & Simonoff, 1999b). In a few cases (such as with autism, schizophrenia, bipolar disorder, and attention deficit disorder with hyperactivity), genetic factors account for most of the variance in populations—over 70%. For the great majority of psychological characteristics, however, the genetic effects are not as strong. Thus, the heritabilities of unipolar depression, delinquency, and parenting qualities are in the 20% to 40% range.

Two different answers can and should be given to the question of how much faith we can place on these estimates. First, there is every reason to believe that they are close to correct. This conclusion is based on the fact that numerous studies have produced broadly comparable findings; that substantial genetic effects are evident from twin, adoptee, and family data; and careful consideration of the findings indicates that nongenetic explanations for the pattern of results found lack plausibility.

The second answer, however, is that the estimates must be regarded as very approximate. This is because the precise figures produced by different investigations are often rather different, and different methods often come up with somewhat discrepant findings. The use of parent reports and child reports, and of twin and adoptee data, have made these points apparent. In the past, arguments have raged over whether the heritability of, for example, IQ is this figure or that figure, but the important thing to bear in mind is that it does not really matter. With respect to some traits, there is real doubt whether the heritability in the populations studied is 20% or 40% or 60%. There are no theoretical or policy implications from such wide estimate variations (surprising though that may seem), because all indicate substantial genetic effects and the figures are population specific; that is, they apply only to the particular samples studied at a particular time. Even a heritability as high as 90% does not mean that changed environmental conditions could not make a huge impact. This is not just speculation; the findings with respect to height both in childhood and in adult life show the reality (Tizard, 1975). Height is one of the most strongly genetically influenced of all human characteristics, but it has increased enormously over the course of the 20th century (Kuh, Power, & Rodgers, 1991; van Wieringen, 1986), almost certainly due to improved nutrition. Genetic influences on the timing of the menarche are also strong but, again, the age of menarche has fallen greatly over the last 100 years or so (Tanner, 1962). It is clear that environmental factors can bring about major changes in features that are strongly genetically influenced.

Despite this reservation, we may conclude that there can be no doubt about the importance of genetic (as well as experiential) influences on individual differences, especially with respect to persistent traits and chronic or recurrent disorders. Genetic influences are particularly strong with respect to several mental disorders, where the evidence from other biological studies indicates the likelihood that brain abnormalities are implicated in the causal processes. This applies, for example, to autism (Bailey, Phillips, & Rutter, 1996; Lord & Bailey, in press) and schizophrenia (Keshavan & Murray, 1997), and, in both cases, the quantitative genetic findings point to the likelihood that several interacting genes are involved—that is, synergistic interaction among genes may be implicated.

Strengths and achievements. Several other, rather different aspects of the genetic findings warrant emphasis. To begin, it is necessary to note the pervasiveness of genetic influences across all psychological traits, even those involving attitudes or social behavior (Plomin, 1994). Thus, genetic effects have been found for features as diverse as divorce (Jockin, McGue, & Lykken, 1996; McGue & Lykken, 1992), religiosity (Eaves, D'Onofrio, & Russell, 1999), and various aspects of parenting style (Kendler, 1996a). Critics have been quick to scorn such findings, arguing that it is ridiculous to suppose that there could be a gene for divorce or crime (Rose, 1995, 1998). They are right, of course, that it is extremely unlikely that such a gene could ever occur. They also point to the indefinite boundaries of the phenotype, or behavior, being studied. Both arguments, however, miss the point completely. The message is that the workings of the mind are based on the functioning of the brain, and that genetic influences apply to individual differences on all somatic features.

It must be anticipated, therefore, that there will be a genetic effect on all behaviors. Biologically speaking, this is exactly what one would expect, and what has been found. The challenge is to find out how these genetic effects are mediated because, obviously, they are most unlikely to operate directly on the social behavior as observed.

The second point is that the genetic evidence is equally consistent in showing the major importance of nongenetic influences (McGuffin & Rutter, in press; Rutter et al., 1999b). With many psychological characteristics, their influence is somewhat greater than that of genetics and, even with the traits that are most strongly genetically influenced, environmental effects are far from trivial.

A third important finding in the realm of psychopathology is that it is quite common for the same genetic factors to underlie supposedly different types of mental disorder. For example, with respect to anxiety and depressive disorders, much of the shared variance is explicable in terms of the temperamental or personality trait of neuroticism (Kendler, 1996b). Similarly, there are shared genetic factors involved in the liability to oppositional/defiant, conduct, and hyperkinetic/attention deficit disorders, even though the prevailing psychiatric classification diagnostic systems classify them as separate conditions (Rutter, 2001). A somewhat related point is that often the genetic factors seem to operate across a broadly distributed continuum, rather than just at the extreme disorder end of apparent abnormality (Plomin & Rutter, 1998). As with the rest of the internal medicine, it seems that many genetically influenced risk factors are dimensional rather than categorical—a finding that has important implications for our understanding of causal processes. In the past, there has often been the assumption that causal influences operate on disorders as such, and that these influences are different from those that underlie individual differences within the normal range. It is now evident that often this is not the case. Just as differences in cholesterol level across the whole range from unusually low to unusually high are associated with variations in the risk for ischaemic heart disease, so, too, are quantitative differences in temperamental features associated with variations in the risk for psychopathology.

A further important finding is the occurrence of gene–environment interactions (Rutter & Silberg, in press). The evidence is quite limited, but several studies have suggested that in the case of both antisocial behavior and depression, environmental risk factors operate most strongly with genetically vulnerable individuals. In other words, adverse environments often have the least impact on those who are not genetically vulnerable and the most impact on the genetically susceptible.

The last example of a specific finding of importance concerns the differentiation between shared and nonshared environmental effects (Plomin & Daniels, 1987). It was argued that results suggested that for most psychological features, the strength of nonshared effects outweighed those of shared effects. This finding was important in serving as a reminder that it could not be assumed that environmental influences impinged equally on all individuals in the same family. As a consequence, environmental influences often serve to make children in the same family different, rather than the same.

The potential importance of the above findings is considered in conjunction with the findings on molecular genetics; however, it would seem evident that there is a powerful case for the importance of genetic influences on psychological characteristics. Thus, it is necessary to consider some of the problems associated with the ways in which quantitative genetics have been presented. These have taken several different forms.

Misleading claims. The first problem is that there are misleading presentations of findings (see Rutter, Pickles, et al., 2001; Rutter et al., 1999a). For example, one study found that shared environmental effects were substantially stronger than nonshared ones, but the abstract made no mention whatsoever of shared effects and emphasized only the rather minuscule nonshared effects (Pike, McGuire, Hetherington, Reiss, & Plomin, 1996; see Rutter, 2000e). Other examples include failures to mention serious attrition biases in sampling, downplaying of the environmental range problems in adoptee samples, and the use of simplifying assumptions in modeling when it is known from other evidence that the assumptions are wrong (e.g., that supposedly there is no assortative mating, gene–environment correlations, or gene–environment interactions in the case of antisocial behavior). All too often, claims have been maintained long after the empirical evidence has indicated that substantial modifications were necessary. Thus, the original claim that nonshared environmental effects far outweigh shared ones is no longer supportable as a general proposition. Once continuities over time and measurement error are taken into account, there is much more of a balance between shared and nonshared effects (see Reiss, Neiderhiser, Hetherington, & Plomin, 2000; Rutter, Pickles, et al., 2001; Rutter et al., 1999a). That does not diminish the importance of the general point that experiences frequently impinge differentially on different children in the same family, but there are too many exceptions to the claim that nonshared effects

predominate for this supposed predominance to be maintained as a rule. What remains of interest, however, is the consistent finding that some maladaptive behaviors with broadly similar heritabilities are usually found in several children within the same family (this would apply to antisocial behavior, for example), whereas others usually affect just one child (this would be more frequent in the case of depression or anxiety).

A second problem has come from misleading extrapolations. For example, several commentators (see, e.g., Harris, 1998; Rowe, 1994; Scarr, 1992) have used the supposed findings on the nonimportance of shared environmental effects to conclude that family features have little or no effect on children's psychological development. The claims on nonimportance of shared environmental effects are themselves overstated but, in this connection, the more important issue is that the shared or nonshared environment effects are inferences that derive from evidence that environmental factors make siblings alike or different. They have nothing to do with whether the environmental influence is within or outside the family. It is quite possible for familywide influences (such as discord or conflict) to have largely nonshared effects just because conflict impinges more on one child than another and/or because some children are more vulnerable to the effects of discord (as a result perhaps of temperamental features). It is rare for behavior geneticists to make use of evidence deriving from nongenetic strategies. As a consequence, they have frequently ignored well-based findings that run counter to their claims.

In addition, all too often there has been a cavalier ignoring of evidence either on the importance of restricted samples (see Stoolmiller, 1999) or of violation of key assumptions of the twin design (Rutter, Pickles, et al., 2001; Rutter et al., 1999). Thus, for example, it is evident that with respect to both antisocial behavior and depression, there is usually likely to be a violation of the equal environments assumption (EEA), and that is indeed what has been found when it has been looked for in an appropriate manner: the environmental risk factors for both antisocial behavior and depression are correlated with genetic susceptibility, but, in addition, these same risk factors are significantly associated with differences in psychopathology within monozygotic pairs who, of course, are genetically the same. The concern here is not that a failure to take this violation of EEA into account has rather inflated heritability estimates (although that is true), but rather that there is a failure to recognize the important implication that some genetic effects operate indirectly via the environment, rather than directly in a way that is separate from environmental risk. It is usual in presenting quantitative genetic findings to incorporate gene–environment correlations and interactions within the genetic influence term. The rationale for this, apart from convenience, is that the genetic factors "drive" what is happening. In a sense, this is the case, but the effects on the psychological features are dependent on the combination of genetic and environmental factors working together—not just additively, but synergistically (see Rutter & Silberg, in press; Silberg, Rutter, Neale, & Eaves, 2001).

A similar problem has occurred with the extrapolations of the pervasive finding of gene–environment correlations (Plomin & Bergeman, 1991). This finding has been used to argue that many of the risk effects attributed to environmental factors are actually genetically mediated. The charge that most psychosocial research has failed to consider this possibility, and hence that many claims regarding psychosocial influences are unwarranted, is fair. Although downplayed by geneticists, however, the same genetic research shows that there is environmental risk mediation (see Rutter, 2000a). Also, it is misleading to suppose that just because genetic factors influence the occurrence of an environmental risk factor, this must mean that the risk process is genetically mediated. This assumption does not follow because there is no necessary connection between the causes of the origin of a risk factor and its mode of risk mediation—as the example of smoking clearly illustrates (see Rutter, Silberg, & Simonoff, 1993).

Perhaps, most crucially, what has been misleading is the claim that quantitative behavior genetics constitutes a causal theory (Scarr, 1997). It constitutes nothing of the kind. Quantitative behavior genetics does provide a highly effective way to partition the variance, and that is immensely useful for a variety of purposes (including the study of nature–nurture interplay and the developmental processes underlying comorbidity). Knowing that a trait is genetically influenced, however, is of zero use on its own in understanding causal mechanisms. The same, of course, applies to parallel claims with respect to environmental influences. To be of any use for policy or practice, it is necessary to know much more with regard to the specifics and how they work. The point is that genes work in quite a diverse range of ways and the implications are quite different according to the details.

Molecular Genetics

This last point is central to the topic of molecular genetics (see McGuffin & Rutter, in press; Rutter et al., 1999a). A key consideration here is that what is left unanswered by the black box analyses of quantitative genetics

can often be answered through molecular genetics. Molecular genetics does not involve the quantification of genetic effects, but rather the identification of specific individual genes that are involved in the susceptibility to particular features (either physical or mental).

Findings with respect to psychological characteristics and to psychopathology are still at a very early stage, but already there have been some important findings. Quite a lot has been learned about unusual genetic mechanisms, the discovery of which has provided explanations for what had hitherto been some very puzzling genetic findings on patterns of inheritance that seemed to contravene Mendelian expectations, and patterns of inheritance in which disorders arise at an earlier age in each succeeding generation. Thus, for example, trinucleotide repeat sequences that expand through intergenerational transmission have been shown to be responsible for a range of neuropsychiatric disorders, including the fragile X anomaly (Skuse & Kuntsi, in press). The phenomenon of genomic imprinting (see Keverne, 1997; Ohlsson, Paldi, & Graves, 2001; Reik & Walter, 2001), in which gene expression is altered according to whether the gene is transmitted through the father or through the mother, is another fascinating phenomenon that has been shown to be implicated in two syndromes—the Prader-Willi syndrome and Angelman syndrome—both of which are associated with mental retardation. Mitochondrial inheritance has also been found to be involved in several neurological disorders. This fact is of interest because the mitochondria, which are outside the nucleus, are transmitted only through the mother and because mutations arise throughout life. Also, we have a better understanding of Lyonization, the process by which one of the X chromosomes in females is switched off (Avner & Heard, 2001). This process incidentally, creates a mechanism that constitutes one of the ways in which identical twins occasionally differ with respect to wholly genetic single-gene disorders. Also, microdeletions of chromosomes may, it now seems, be responsible for a proportion of cases of mental retardation (Flint et al., 1995; Knight, Udalova, et al., 1999).

Over the last few years, a few specific individual genes have been identified that are involved in the liability to mental disorders. The ApoE4 allele that is involved in the liability to Alzheimer's disease is the best known in the psychopathological arena (Plassman & Breitner, 1996; Rubinsztein, 1995), but there are also genes that affect dopamine metabolism that have been implicated in attention deficit disorder with hyperactivity and other child psychiatric conditions (Levy & Hay, 2001).

In the field of internal medicine, it has been particularly important that genes have been associated with very marked individual variations in response to environmental hazards (Rutter, 2000a). This phenomenon has become evident, for example, with respect to smoking and coronary artery disease, vulnerability to the sequelae of head injury, and responses to malaria and other infections (Hill, 1998; Knight, Regan, et al., 1999). In addition, research is beginning to identify genes that influence individual responses to therapeutic medication—the field of pharmacogenetics (Evans & Relling, 1999). In other words, the black-box concept of gene–environment interaction, which derived out of quantitative genetics, is now being shown to have meaningful substance through advances in molecular genetics.

Finally, research in the field of reading difficulties has shown that there is the possibility that different genes may be involved in different aspects of syndromes that had hitherto been thought to be relatively unitary (Grigorenko et al., 1997; Grigorenko, Wood, Meyer, & Pauls, 2000). It is too early to know whether these findings will prove to be solid and, more specifically, whether this genetic effect on specific features within syndromes will be found to apply to other conditions. Nevertheless, already the findings serve as a reminder that in understanding causal processes, it is necessary to appreciate that mental disorders may involve several different causal pathways that are responsible for different aspects of syndromes.

Two very important publications occurred in February 2001: both *Science* and *Nature* announced the draft sequence of almost the entire human genome. There is no doubt that this was quite a remarkable scientific achievement, as well as one that has produced a few surprises. I consider below why and how this achievement is going to make a real difference to the discovery of susceptibility genes associated with psychological features, as well as those with any other aspect of the human condition.

Misleading claims. The downside of molecular genetics has involved both what has been said and what has not been brought out. With respect to the former, the most obvious hype and scientific evangelism have concerned claims both about the speed with which susceptibility genes (genes that affect the liability of some trait or disorder, but which do not determine the trait or disorder directly) are likely to be discovered and the extent to which this is going to have clinical utility. There has been much talk about how it will soon be possible to have genetic profiles at birth that will enable us to know all about our propensities and susceptibilities, and the diseases that we are going to develop. This talk is highly misleading for several different reasons. As Weatherall (1999, p. 2008) put it in a straightforward summary conclusion: "Many state-

ments being made about the imminence of accurate predictive genetics . . . are simply not true."

What is true is that the sequencing of the human genome will make it much easier than before to identify disease genes, because candidate genes can readily be detected using computers to question public sequence databases, which can then be followed up with mutation screening of plausible candidates. This is where the tool of bioinformatics really comes into its own. Databases can be used to search the human genome for proteins that are similar in other organisms, or to identify all the proteins of a particular family (such as those affecting a particular set of disease processes). Already, this strategy has facilitated the identification of genes implicated in the causation of important human diseases (such as complete color blindness or early-onset Alzheimer's disease; see International Human Genome Sequencing Consortium, 2001). The first caution, however, is that it is going to be much more difficult to discover susceptibility genes for multifactorial disorders, especially when genes play only a contributory role in the context of major environmental influences. The difficulties that have attended the search for susceptibility genes for a well-defined disorder such as juvenile diabetes (Todd, 1999) provide a warning of how it is likely to be even more difficult in the field of mental disorders, in which definition of a phenotype is so much more problematic. It may turn out, as enthusiasts have claimed (Plomin & Crabbe, 2000), that we will soon be awash with susceptibility genes for psychological characteristics, but I rather doubt claims on the speed with which this will happen. The more important caveats, however, are of a different kind.

Three main points need to be stressed. First, finding the susceptibility genes is the relatively easy part. What is likely to prove much more difficult is determining what these genes do; that is, their effects on proteins and the ways in which these protein effects lead to particular psychological outcomes (see Rutter, 2000b). Research will be needed in three broad areas: transcriptomics (the study of which genes are switched on in particular cells), proteomics (which looks at the interplay among proteins in cells), and structural genomics (which tackles the question of the three-dimensional structures of all the proteins encoded by genes). Although all of this is potentially doable, solving all the research problems in this overall field of functional genomics is going to be quite difficult and will undoubtedly take a long time. Second, when dealing with multifactorial traits, and that means virtually the whole of those involved with psychological features, there is the further challenge of understanding how genes are involved in the interplay with environmental risk factors. This requires advances in the field of molecular epidemiology and, for this to succeed, there will have to be advances in the measurement of environmental risk factors on very large samples, at least as big a challenge as in the field of molecular genetics itself. Genetic enthusiasts seem to have paid almost no attention to this need. Third, there has been a great underplaying of the extent of geographic and ethnic variability in genetic effects (see Rutter, 2001). All too often, enthusiasts write or speak about genetics as if, because genes are a fixed part of the constitution, their effects should be universal across populations. However, they are not. For example, there is huge geographical variation in which particular alleles are responsible for thalassaemia (sickle cell disease; see Weatherall & Clegg, 2001); and, for reasons that remain ill understood, the apolipoprotein E4 seems to carry less of a risk for Alzheimer's disease in individuals of African or Hispanic heritage (Farrer et al., 1997).

Psychiatric molecular genetics got off to a thoroughly bad start with premature claims that subsequently had to be withdrawn (see Rutter, 1994). It is to the credit of the researchers involved in the study of affective disorder that they were quick to note the problems and to withdraw their own earlier claims (Kelsoe et al., 1989). Withdrawal of the claims with respect to schizophrenia took quite a bit longer. It continues to prove incredibly difficult to replicate findings in the identification of susceptibility genes for multifactorial psychiatric disorders. Surprisingly, however, distinguished researchers still allow themselves to get carried away with the excitement of unconfirmed findings. For example, a few years ago there was a report that one of the genes responsible for individual variations in intelligence had been discovered (Chorney et al., 1998), and the media went to town with academics making astonishing statements that this revolutionized our thinking about the importance of genetic factors in intelligence. The research, however, had not taken into account stratification biases, and some years later it still remains unconfirmed by independent investigators. Indeed, the report of DNA pooling as used with a genome wide scan by the same research team did not include the same finding (Plomin & Craig, 2001). Identification of genes that play a role in individual differences in intelligence may well come, but it is dubious whether this will provide an understanding of the basis of intelligence (Rutter, 2000d).

Potential of molecular genetics. How do we come up with an appropriate balance with respect to the potential of molecular genetics? To begin, there is the initial question of whether molecular genetics will

live up to its promise in identifying susceptibility (and protective) genes for psychopathology and psychological traits. The identification of multiple genes of small effect, particularly when the phenotypes are difficult to define and lack strong validity, will be quite difficult. Nevertheless, through the use of multiple research strategies, it is likely that delivery will come (Evans, Muir, Blackwood, & Porkus, 2001; Owen, Cardno, & O'Donovan, 2000) even if it takes longer than some expect. It may be, however, that greater attention will need to be paid to epigenetic misregulation of genes, as well as DNA sequence variation (Petronis, 2001). In essence, epigenetics refers to the genetic processes involved in the expression of particular genes in individual cells. Although, ordinarily, the genotype is the same across cells, its structural and functional consequences are not. Both genomic imprinting and X chromosome inactivation (see above) are good examples of this kind, but restructuring of DNA methylation during gametogenesis provides the opportunity for de novo epigenetic errors; hormone-induced epigenetic changes also may play a role in the differential susceptibility of males and females to complex diseases.

Assuming that the relevant genes are found, there is a considerable potential for advances in knowledge that should bring worthwhile human benefits (McGuffin & Rutter, in press; Plomin & Rutter, 1998; Rutter, 2001; Rutter & Plomin, 1997). First, and perhaps most crucially, genetic advances should foster research that will lead to a much better biological understanding of the causal processes involved in such serious disorders as autism or schizophrenia. Up until now, biological research has proved frustratingly inconclusive on the specifics of the underlying neuropathophysiology for such conditions. Genetic findings, in and of themselves, will not provide any understanding of such causal processes, but what they should do is provide invaluable leads as to how complementary biological research can identify what is involved. Second, provided that genetic research moves ahead in harness with environmental research, genetic advances should enable us to gain a much greater appreciation of the interplay between nature and nurture. In other words, one of the really important potential gains is that genetic findings should greatly facilitate the study of environmental risk mechanisms. That is not going to be at all easy, both because the effects of single genes are quite minor, and because the same applies to individual environmental risk factors. The cumulative effect of genetic risks, of environmental risks, and especially of their interplay, are very great, but it is clear that the effective study of gene–environment correlations and interactions is going to require attention to many genes, and not just one; and attention to many environmental risk factors, and not just one.

Third, there is substantial potential in the field of pharmacogenetics (Evans & Relling, 1999; Wolf, Smith, & Smith, 2000). With psychopathology, just as in the whole of internal medicine, it is obvious that there are huge individual variations in how people respond to therapeutic medication. Clearly, genetic factors will prove to play an important role in that individual variation. It follows that an understanding of how these operate will be hugely helpful in allowing therapeutic interventions to be tailored in ways that are specific to individuals, and will aid in the understanding of pharmacological actions and how they bring therapeutic benefits.

Fourth, there is a limited potential for using genetic findings to improve the classification and diagnosis of mental disorders. For example, genetic findings could help in sorting out which social deficits are part of the autism broader phenotype and which, although superficially similar, are not, because they do not involve the same susceptibility genes (Rutter, 2000b). The reason why this constitutes a more limited potential is that most diagnoses are based on pathophysiology and not on causal factors. For example, the diagnosis of diabetes is based on laboratory findings with respect to glucose metabolism, and not on whether the patient has a specific susceptibility gene. Similarly, coronary artery disease is diagnosed on the basis of atheroma of the coronary arteries, and not on the role of smoking, raised cholesterol levels, or clotting factors in etiology.

In theory, gene therapy could play some role in the treatment of mental disorders, but it is likely that this role will be quite small; not because of the difficulties at the moment in gene delivery, but rather because of the problems of applying this technique to multifactorial disorders. A further potential benefit will come from the individualization of genetic risks, an advance that clearly will be of benefit in genetic counseling (McGuffin & Rutter, in press; Rutter & Plomin, 1997).

The huge potential benefits are obvious, even though it is clear that it will take quite some time for molecular genetic findings to lead to major improvements in clinical practice. In recognizing the reality of these great benefits, it is equally important that attention is paid to the attendant ethical risks involving discrimination in its many various forms, and the possibility of relative neglect of public health issues and of the need to study, and take action on, environmental risks (see Buchanan, Brock, Daniels, & Wikler, 2000; Rutter, 1999a). It should be possible to avoid these disadvantages, but only if we accept their reality and act accordingly.

NURTURE: ENVIRONMENTAL RISK AND PROTECTIVE MECHANISMS

Strengths and Achievements

In considering next the advances in understanding of environmental risk and protective processes, the first point that stands out is that there is good evidence of the environmentally mediated effects of specific environments (Rutter, 2000a). It has been necessary for research to address two serious issues: the need to check that the effects are truly environmentally—rather than genetically—mediated, and that the direction of causal influence is from the environment to the child, rather than the reverse. A considerable range of effective research strategies is available for these purposes (Rutter, Pickles, et al., 2001), including multiple variants of the twin design, several varieties of adoptee design, natural experiments, migration strategies, and studies of intervention effects. The research findings have been consistent in showing the psychopathological risks associated with (1) persistent discord and conflict—particularly when it involves scapegoating or other forms of focused negativity directed toward an individual child, (2) a lack of individualized personal caregiving involving continuity over time (as is usually the case with an institutional upbringing), (3) a lack of reciprocal conversation and play, and (4) a negative social ethos or social group that fosters maladaptive behavior of one kind or another. The risk and protective factors involve not only the immediate family, but also the peer group (Rutter, Giller, & Hagell, 1998), the school (Maughan, 1994; Mortimore, 1995, 1998), and the broader social community (Leventhal & Brooks-Gunn, 2000). It is also important that research findings have indicated that various factors once thought to carry serious risks for mental disorder, in actuality do not. Thus, for example, it is clear that parental loss or separation carries quite mild risks unless the loss leads to impaired parenting or other forms of family maladaptation. Similarly, it has long been clear that it matters little when weaning takes place, when children are toilet trained, or the type of disciplinary technique used (Maccoby & Martin, 1983).

An important distinction that increasingly has been drawn, as a result of empirical research findings, is that between proximal and distal risk processes (see Rutter et al., 1998). Thus, for example, although parental loss carries with it little direct (or proximal) psychopathological risk, it is important because, in certain circumstances, it predisposes to other psychosocial risks and makes adaptive parenting more difficult. Poor parenting does predispose to mental disorder, whether or not it is associated with parental loss; whereas parental loss does not predispose to disorder, if poor parenting does not follow. In the same way, poverty has a quite limited role as a proximal risk factor, but is rather more important as a distal risk factor that makes cohesive and harmonious family functioning more difficult. The same seems to apply to inner city life: It is statistically associated with increased rates of child psychiatric disorder, but these risks are mediated, not by the effects of city life directly on children, but rather through their effects on family functioning and their associations with less positive schooling (Rutter, 1979a; Rutter & Quinton, 1977).

A major shift in studies of psychosocial risk factors has come with the awareness of the major individual differences in response, and the huge heterogeneity in outcome. The findings have focused attention on the phenomenon of resilience, meaning relatively good psychological functioning despite the experience of serious psychosocial adversities (Rutter, 1999b, 2000c). There have been important methodological challenges to overcome in studying resilience, but there is now evidence to demonstrate the reality of the phenomenon. Some useful leads on the factors that promote resilience have been obtained; but, so far, they are just that—leads, rather than established knowledge on mechanisms.

For a long time, one of the findings that made many people reluctant to take seriously the possibility that environmental risks played a major role in the causation of mental disorder was the apparent lack of specificity of effects (Steinberg & Avenevoli, 2000). The view was that if negative experiences predisposed to all the ills of humankind, they might have a contributory predisposing role, but it was unlikely that they constituted a key causal influence. Two things have changed that situation somewhat. First, there is now some evidence supporting a degree of specificity of effects. For example, an institutional rearing has been found to predispose to so-called disinhibited attachment problems and patterns of inattention and overactivity (see Rutter, in press-a; Rutter, Kreppner, O'Connor, & the ERA Study Team, 2001). When the institutional rearing has been accompanied by severe global deprivation, but not otherwise, it seems to predispose to atypical quasiautistic patterns and cognitive impairment. Severe and unusual stress experiences (such as exemplified by shipwrecks) are associated with a range of phenomena that has come to be termed posttraumatic stress disorder (Yule, in press). This is by no means the only form of psychopathology associated with severe and unusual stress, but it is a characteristic pattern. Family disorganization and discord are particularly associated with antisocial behavior (Rutter et al., 1998). In adults, stresses involving the threat of future danger tend to be associated with anxiety, whereas

those involving the feeling of psychological loss seem to be particularly likely to predispose to the onset of a depressive disorder. The same most likely applies in childhood (Eley & Stevenson, 2000). It should be noted that it is not the physical loss that seems important, but rather the long-term threat that is implicit in the loss of a love relationship, or from a public humiliation. Thus, although there are many nonspecific effects of psychosocial adversity (Steinberg & Avenevoli, 2000), it has also become evident that there is more specificity than had been apparent some years ago.

The second point is that many adverse experiences involve a range of disparate elements, each of which may carry a relatively specific risk effect. Because these are multiple, however, there is a false impression of nonspecificity. Cigarette smoking provides an obvious example: It predisposes to an apparently heterogeneous range of medical disorders—including osteoporosis, lung cancer, coronary artery disease, emphysema, and wrinkling of the skin—which would seem to suggest a lack of specificity. This assumption, however, is incorrect (see Rutter, 1997). With several of these outcomes, it is known that the effects are specific—involving features such as carcinogenic tars, carbon monoxide, or nicotinic effects on blood vessels. It is just that cigarette smoking involves quite a collection of different risk processes. Comparable evidence is lacking with respect to psychosocial risks, but it is highly likely that the same applies. For example, parental depression involves genetic risk (i.e., it is more likely that offspring will develop depressive disorders themselves), but parental depression also predisposes to family breakdown and family discord, which, in turn carry risks for antisocial behavior.

At one time, almost all the focus was on adverse rearing experiences, but it has become apparent that it is also necessary to pay attention to the possibility of prenatal risks of various kinds. It is now clear that a mother's ingestion of large amounts of alcohol during the early months of pregnancy carries risks of damaging effects on the development of the fetus, effects that are evident later in relation to both somatic abnormalities and behavioral disturbance—particularly in the form of inattention and overactivity (Stratton, Howe, & Battaglia, 1996; Streissguth & Kanter, 1997). There are probably comparable risks associated with other forms of substance abuse in pregnancy (Mayes, 1999), and there is some indication that prenatal damage of other kinds is also associated with increased psychopathological risks (Munk-Jørgensen & Ewald, 2001).

Finally, there has been the successful development of various forms of psychosocial intervention—both to prevent psychopathology (Offord & Bennett, in press) and to alleviate disorder (Brent, in press). Knowledge on the mechanisms involved in therapeutic efficacy is decidedly limited still (but see Forgatch & De Garmo, 1999; Vitaro, Brendgen, Pagani, Tremblay, & McDuff, 1999); nevertheless, there is good evidence that certain forms of intervention do provide real and worthwhile benefits.

Misleading Claims

The period extending from the 1950s to the early 1970s may be viewed as one of rampant environmentalism. There was an uncritical acceptance of the lasting and irreversible effects of early childhood experiences and of the extent to which social disadvantage constituted a major cause of mental disorder. The initial claims with respect to maternal deprivation (Bowlby, 1951) constitute one example. The extrapolation to the supposed permanently damaging effects of day-care (World Health Organization Expert Committee on Mental Health, 1951) constitutes an even more striking example, as does the naive expectations of some people with regard to how much could be achieved by brief interventions in the preschool years, such as those initiated by Head Start (see Clarke & Clarke, 1976; for balanced reviews see Zigler & Styfco, 1997; Zigler & Valentine, 1997). The background was one of a well-justified concern to better the lives of young children, together with an awareness of the many things that needed to be righted in the care of such children. The defenders of the field would undoubtedly argue that it was necessary to overstate claims of environmental effects to bring about political action. That may well have been true, but, from a scientific perspective, there was a serious neglect of the need to provide rigorous tests of environmental mediation hypotheses, and a comparable ignoring of the need to differentiate between person effects on the environment and environmental effects on the individual (see Bell, 1968; Bell & Chapman, 1986). In addition, there was a failure to appreciate the substantial continuities in environmental disadvantage and, therefore, an exaggeration of the extent to which persistent sequelae derived from the early environment, rather than from continuing psychosocial adversity (see Clarke & Clarke, 1976, 2000).

The late 1970s to early 1980s saw substantial criticisms of the exaggerated psychosocial influences claims, and in the late 1980s to early 1990s there was an excessive swing of the pendulum in the opposite direction in terms of a denial of any substantial environmental effects within the normal range. Unfortunately, this polarization between nature and nurture has remained all too widespread, and has been accompanied by a considerable reluctance among some researchers to accept the need to take seriously the

possibility of genetic mediation (see, e.g., Baumrind, 1993; Brown, 1996). Also, most psychosocial research continues to use designs that provide inadequate tests of environmental mediation.

Far too much psychosocial research, even today, is involved with the demonstration of statistical associations between some hypothesized risk factor and some postulated outcome variable, without any attention paid to the necessity of differentiating between risk indicators and risk mechanisms. As a consequence, remarkably little is known about psychosocial risk processes; and even less is known about the effects of such risk processes on the organism (and, therefore, why and how effects persist when they do). In addition, little is known about individual differences in response to psychosocial stress and adversity; and there is almost total ignorance with regard to the environmental factors that are responsible for the major secular trends that have been evident over the course of the 20th century (see Rutter & Smith, 1995). There is good evidence of a major rise in the level of antisocial behavior, of substance abuse problems, and of suicidal rates among young males—to mention but a few examples. The speed of the rise indicates that some environmental influence must have been responsible (although possibly enhanced by the multiplying effect that could come from gene–environment correlations; Dickens & Flynn, 2001), but there has been little systematic research into possible causes.

The dismissal by some commentators of the importance of psychosocial influences on psychological development and on psychopathology was clearly misguided. There is good evidence that there are important effects, but the knowledge as to how these risks are brought about, and how effects sometimes persist to much later stages in development, is much less than psychosocial enthusiasts would have us believe.

Potential of Psychosocial Research

The potential of psychosocial research is considerable. If it is to be actualized, however, much more attention will need to be paid to both the conceptual and methodological challenges. Without doubt, one of the major growth areas is going to be the study of gene–environment interplay (Rutter & Silberg, in press). On the whole, the empirical research findings suggest that genetic vulnerabilities operate, in part, through their role in bringing about an increased susceptibility to environmental hazards. It seems that ill effects following psychosocial stress and adversity are relatively minor in those who are not genetically at risk (Rutter, 2000a; Rutter et al., 1997; Rutter, Pickles, et al., 2001). This is not a universal tendency, and there may well be circumstances in which the reverse is the case (see Rowe, Jacobson, & van den Oord, 1999). Nevertheless, what is evident is that psychosocial researchers need to make greater use of genetically sensitive designs and that if they do, there should be a substantial payoff in understanding environmental risk and protective mechanisms. In that connection, more use could be made of studies with animals, as well as studies with humans.

Several phenomena warrant research attention. First, both animal and human studies have shown the reality of sensitization and steeling effects (Rutter, 1981a; Wachs, 2000). That is, stress experiences make individuals either more resistant or more vulnerable to later psychosocial hazards. The question then is what is it about the individual, or the experience, that leads to one outcome rather than the other. There is some suggestion that milder stresses, or, more likely, ones that are accompanied by successful coping and adaptation, tend to foster steeling, whereas overwhelming stresses that bring about maladaptation and unsuccessful coping lead to sensitization (see Rutter, 2000c). This matter, however, has been subject to remarkably little systematic investigation.

The related phenomenon of resilience warrants similar attention. It is clear that many different features are likely to be involved in resilience (Luthar, Cicchetti, & Becker, 2000; Rutter, 1999b, 2000c), including prior experiences, how the individual deals with stress at the time, inherent qualities of the individual, and subsequent experiences. At one time, writers on the topic tended to imply that vulnerability and invulnerability were general characteristics of the individual, but that is most unlikely to prove to be the case. People may be resilient with respect to some types of experiences and yet very vulnerable with respect to others.

A further phenomenon is that of so-called "kindling" effects (Kendler, Thornton, & Gardner, 2000, 2001; Post, 1992). This term refers to the phenomenon of individuals becoming less responsive to environmental stressors as a result of having developed a disorder. It appears that in some circumstances the experience of disorder brings about changes in the organism that predispose it to perpetuation that is relatively independent of the environment. Thus far, research has scarcely begun to chart the qualities and frequency of the phenomenon, let alone the mechanisms that are implicated. Future systematic empirical study is warranted.

Finally, there is the important research priority of determining the changes in the organism that have been brought about by psychosocial experiences and of the ways in which such changes predispose the organism to the continuation or occurrence of psycho-

pathology. Many possibilities exist (Rutter, 1989a; Rutter, O'Connor, & the ERA Study Team, 2001). Do the mechanisms involve cognitive and affective sets, self-concepts, and internal working models? Do they involve changes in the neuroendocrine system? Do they come about through effects on styles of interpersonal interaction? Are they brought about through effects on individual behavior that predispose people to act in ways that engender later stresses or adversity? Or, are the effects a consequence of changes in brain structure or function? Research is only just beginning to tackle these questions, and it is important that more be done. If psychosocial research is to deliver effectively on its very considerable potential, it is essential that psychosocial research be a part of biology, and not separate from it.

DEVELOPMENTAL PROCESSES

Strengths and Achievements

An immense amount has been achieved with respect to increasing knowledge on the course of development, and on some of the key processes that are involved. A few examples serve to illustrate the advances. It has become clear that brain development involves initial proliferation of neurons and synapses, with extensive neuronal migration. This overproduction of nerve cells and connections is then followed by a selective pruning, which serves to fine-tune brain development with respect to both structure and function (Goldman-Rakic, Bourgeois, & Rakic, 1997; Greenough & Black, 1992; Greenough, Black, & Wallace, 1987; Nelson & Bloom, 1997). In other words, the biology of brain development is probabilistic, such that there is a genetic programming of the general pattern and course, but extensive opportunities to correct the process of development in accord with both environmental input and the workings of the brain, in terms of cell–cell interactions. Much of this development takes place during the early years of life, but it is also apparent that development continues for much longer, the timing varying across different parts of the brain.

Similarly, much has been learned about the course of psychological development (see Rutter & Rutter, 1993; Shonkoff & Phillips, 2000) with respect, for example, to the development of mentalizing skills, self-concept, social attachments and relationships, and emotional expression. Long-term longitudinal studies have also been crucially important in showing the extent to which people's behavior in childhood predicts their stressful experiences in adult life (Champion, Goodall, & Rutter, 1995; Quinton, Pickles, Maughan, & Rutter, 1993; Robins, 1966; van Os, Park, & Jones, 2001). The findings have highlighted the need to consider the origin of individual differences in experiences of stress and adversity (Rutter, Champion, Quinton, Maughan, & Pickles, 1995); such origins include people's actions in shaping and selecting environments and societal influences, as reflected, for example, in housing policies or racial discrimination.

There also has been documentation of important gender differences, for example, in relation to the rise of depressive disorders (Bebbington, 1996; Silberg et al., 1999) and eating problems (Lucas, Beard, O'Fallon, & Kurland, 1991; Pawluck & Gorey, 1998) in females during late adolescence; the ebb and flow of gender differences in antisocial behavior as they are evident across the lifespan (Moffitt, Caspi, Rutter, & Silva, 2001); and the timing of the onset of schizophrenia (Castle, Wessely, van Os, & Murray, 1998; Tarrant & Jones, 2000). Remarkably little, however, is known about the mechanisms involved in the causes of these gender differences.

One of the important elements that has derived out of research into biological development has been the awareness of the likely importance of epigenetic and of chance effects (Jensen, 1997; Molenaar, Boomsma, & Dolan, 1993). The probabilistic nature of biological development means that some of the variations will be a consequence of perturbations of a quasirandom nature, rather than the effects of specific environments or genetic programming. At a group level, these follow a meaningful pattern; but at an individual level, they are unpredictable (see Rutter, in press-b). Thus, for example, minor congenital anomalies are much more likely to occur in infants born to elderly mothers and are more common in twins than in singletons (Vogel & Motulsky, 1997). There is probably no specific cause of why one particular anomaly is found in any specific individual, however. Similarly, there is a universal pattern of one of the two X chromosomes possessed by females to be suppressed, but which one seems to be determined largely by chance. It might be assumed that such epigenetic effects cannot be the subject of systematic investigation, but that is not entirely the case. Researchers have sought to index developmental perturbations through the study of minor congenital anomalies and so-called fluctuating asymmetry of dermatoglyphic patterns (Naugler & Ludman, 1996). The issue, then, is not the functional consequences of these anomalies or asymmetries (because there are not likely to be any), but rather their use as indices of developmental perturbations that may play a role in deficits or disorders of psychological development.

During recent years, concepts of developmental programming have come to the fore (Bateson & Martin, 1999; Greenough & Black, 1992; O'Brien, Wheeler, &

Barker, 1999). There are at least two different types that need to be considered. First, biological maturation, including brain development, is dependent on the individual having experiences within a broad expectable range (Greenough & Black, 1992; Greenough et al., 1987). Thus, Hubel and Weisel (1965; Hubel, Wiesel, & Le Vay, 1977) showed that the structural and functional development of the visual cortex was dependent on individuals having appropriate visual experiences during a sensitive period of development, during which the structure and function of the visual cortex were established (see Blakemore, 1991; Mitchell, 1989). The programming of development is thereby "experience expectant," to use Greenough et al.'s (1987) term. It needs to be emphasized, however, that a wide range of experiences is adequate for normal development to take place.

Development is also shaped to provide optimal adaptation to the specific environments experienced at the time (Bateson & Martin, 1999; O'Brien et al., 1999)—what may be termed experience-adaptive programming (Rutter, O'Connor, & the ERA Study Team, 2001). This is different in the sense that it is concerned with variations within, as well as outside of, the normal range, and it is concerned not with normal development in an absolute sense, but rather with development that is tailored to the specific environments experienced during the relevant sensitive phase. Thus, for example, in the psychological arena, this sort of programming probably occurs in relation to the ways in which infants' ability to make phonological discriminations is influenced by the language environment that they experience in early life (Kuhl, 1994; Kuhl et al., 1997). The effects are long lasting, although not completely immutable (Werker & Tees, 1992). In the broader field of biology and internal medicine, other examples are evident in the development of immune responses and in metabolic responses to diet (Bock & Whelan, 1991). Thus, for example, babies who are poorly nourished at birth and in early life have been found to be more vulnerable to coronary heart disease, hypertension, and diabetes in midlife (Barker, 1997). This finding is interesting because the association is the reverse of what one finds in adult life; that is, low weight constitutes a risk factor in infancy, but being overweight constitutes a risk factor in middle age. The physiological mechanisms have yet to be properly worked out, but what is hypothesized is that individuals are programmed to deal with poor-quality diets and that they then are at risk if, later on, they are exposed to rich diets. The implication that follows is a challenging one: if there is an attempt, through good feeding, to try to make up in middle childhood for subnutrition in early life, it may actually make things worse. The psychological query is whether there is any equivalent to that phenomenon in relation to psychosocial experiences. Although the answer to this question is not known, the counter-intuitive possibility raises challenging issues that call out for serious investigation. What is clear, however, is that some forms of serious deprivation do lead to persistent sequelae that continue long after there has been restoration of a normal rearing environment, as the findings on Romanian adoptees indicate (see Rutter, in press-b; Rutter, O'Connor, & the ERA Study Team, 2001).

Research has provided some knowledge on age-related progressions in psychopathology (see Rutter, in press-b). Thus, for example, it is clear that early hyperactivity predisposes to later antisocial behavior (Rutter et al., 1998), early conduct problems predispose to substance use and abuse (Rutter, in press-c), substance abuse predisposes to later depression (Rutter, in press-c), and early anxiety problems are often followed by depressive symptomatology (Silberg, Rutter, & Eaves, 2001). It is also well documented that neurodevelopmental abnormalities in childhood are associated with an increased risk of schizophrenia development in early adult life (Keshavan & Murray, 1997). Much less is known, however, about the underlying processes that these progressions reflect.

Developmental research has highlighted several important age-indexed effects of environmental hazards. For example, the effects of unilateral brain injury in infancy are quite different to those seen in later childhood or adult life (Vargha-Khadem, Isaacs, van der Werf, Robb, & Wilson, 1992). It's not that the effects in infancy are greater or lesser than those in later life, but rather that the pattern is different. In adult life, there is a clear lateralization of psychological effects, but this is not found in early life. It is obvious that, in some way, these differences reflect changing patterns of brain plasticity (with respect to the take up or transfer of mental functions), but less is known about what this means with respect to physiological processes (but see Neville & Bavelier, 1998). In relation to psychosocial experiences, there is some evidence that the negative effects of hospital admission tend to be less in infancy or in middle childhood than they are in the toddler age period (Rutter, 1979b), and the effects of an institutional rearing on social relationships seems to be a feature of adverse rearing in early life, rather than adverse experiences later in life (Rutter, 1981b; although this is much less well documented).

Finally, some information has been obtained with regard to the effects of individual differences on the timing of developmental transitions. For example, girls who experience an unusually early menarche tend to have an increase in disruptive behavior (Caspi, Lynam, Moffitt, & Silva, 1993; Stattin & Magnusson, 1990). The stimulus is biological but, in this case, the mediation of

psychological effects seems to be social, with the main mediation being provided by the peer group.

Misleading Claims

The misleading evangelism with respect to excessive claims in the field of development has been of two different kinds. First, in the mid-twentieth century there was a period in which some researchers sought to explain much of development in terms of straightforward biological maturation (Gesell, 1946; McGraw, 1946). During the second half of the twentieth century, there were also many psychological researchers who saw age-related progressions as providing an explanation (Wohlwill, 1970, 1973). There was resistance to unpacking age changes into separate differentiated processes. Critics noted the extent to which so many of the findings relied on cross-sectional studies, rather than longitudinal research (De Ribaupierre, 1989), and they also noted the fact that age was an ambiguous variable (Rutter, 1989b). Not only did the different aspects of biological maturation not necessarily go together (thus, sexual development and intellectual development did not run closely in parallel), but also age reflected experiences as well as biological maturation. It has not proved at all easy to determine which age-indexed change is responsible for altering psychological functions, but clearly that is the research need.

The last decade or so has been accompanied by a different type of evangelism—namely, claims on the extent to which early experiences determine brain development (see, e.g., Kotulak, 1996). There has been a misleading extrapolation of the findings on experience-expectant development to the entirely different notion that higher quality psychosocial experiences in the first 2 or 3 years of life will have a much greater effect than similar experiences later on, because the early experiences bring about a lasting change in brain structure. As several commentators have pointed out, the claims (which come from people outside the field of neuroscience research) are misleading and fallacious for several different reasons (Bruer, 1999). To begin with, brain development is far from over by age 3 years. On the contrary, important changes continue to occur through adolescence (Giedd et al., 1999; Huttenlocher, 1979; Keshavan & Murray, 1997; Sowell, Thompson, Holmes, Jernigan, & Toga, 1999). Also, it is not the case that neuronal growth stops in early life or that plasticity is lost after the infancy years. Animal studies have shown that neuronal growth and increase in number of synapses can and does take place in later life, at least with respect to certain parts of the brain, such as the hippocampus and cerebellum (Diamond, 1991; Eriksson et al., 1998; Gould, Reeves, Graziano, & Gross, 1999; Kempermann, Kuhn, & Gage, 1998; Kleim et al., 1998; Klintsova, Matthews, Goodlett, Napper, & Greenough, 1997; Lowenstein & Parent, 1999).

Moreover, research in humans using structural imaging has shown the effects of later experiences. The increased size of the posterior hippocampus in London taxi drivers (who have to memorize the locations of all London streets and all routes—a process known as "the knowledge"—which usually requires several years of study) provides a striking example (Maguire et al., 2000), as do findings with Braille readers (Sterr et al., 1998) and violinists (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). It is not known how far there is brain plasticity after the first part of childhood, nor the extent to which it varies across different parts of the brain or brain systems. There is some evidence that later learning may be mediated in different ways than in early learning. For example, one study showed that the parts of the brain used in learning a second language after the postinfancy years were different than those parts of the brain used with initial language learning (Kim, Relkin, Lee, & Hirsch, 1997). Nevertheless, what is clear is that the assumption that later experiences necessarily have only minor effects is clearly wrong. Experience-dependent learning (Greenough et al., 1987), in which individualized experiences have neural effects, goes on throughout life. This learning is different from developmental programming, but also involves experiential effects on the brain. It should be added that although it is obvious that the workings of the mind must be based on the functioning of the brain, remarkably little is known about structure–function links.

In addition, little is known about the mechanisms involved in the risks that stem from pre- and perinatal problems, once the effects leading to gross handicap are put aside. Why, for example, are there replicated associations between pre- and perinatal abnormalities and later schizophrenia (McDonald, Fearon, & Murray, 2000) or suicide (Jacobson et al., 1987; Salk, Lipsitt, Sturner, Reilly, & Levat, 1985)? Some of the mediators that seem to be obviously relevant have not been proven to be so. For example, very low birthweight is associated with a marked increased in brain scan abnormalities, and is also associated with an increased risk of psychological impairment. It would seem reasonable to suppose that the brain scan abnormalities would be associated with, and perhaps responsible for, the cognitive impairment, but several studies have failed to find this (Cooke & Abernethy, 1999; Stewart et al., 1999). Why not? The puzzle remains.

Potential for Developmental Research

The potential for developmental research is obvious, as indicated by the range of questions already outlined. It is important to note several areas of particular promise, however, starting with functional brain imaging as used in relation either to specific psychological tasks or to the administration of particular pharmacological substances (Ernst & Rumsey, 2000). One of the major technological developments in recent years has been the establishment of magnetic resonance imaging (MRI). The spatial resolution is better than with positron emission tomography, which preceded it, and MRI does not have the disadvantage of radiation side effects. During the last few years there have been some striking successes in showing which areas of the brain subsume particular psychological functions (see, e.g., Fletcher et al., 1995; Schultz et al., 2000). Functional imaging has provided a new way of testing hypotheses about differences between particular psychological processes and also differences among clinical groups in the ways in which they deal with particular psychological tasks. There is no doubt that much will be learned through functional imaging, provided that a rigorous hypothesis-testing approach is followed and the expertise in physics is accompanied by equivalent expertise in psychology. Nevertheless, certain cautions are necessary. The technique is often "sold" as a means of actually seeing the brain in action, but this is not quite so. What MRI does show are changes in blood flow and oxygen take-up, which reflect metabolic activity, but provide only a very indirect means of investigating brain physiology and neurochemistry. It is important, also, to appreciate that just because changes in brain function can be seen, does not necessarily mean that the biology of the brain has caused whatever changes in psychological functioning are being investigated. Thus, it has been found that the changes in brain function that can follow psychological treatments of obsessive-compulsive disorder closely parallel those that are brought about by therapeutic medication (Baxter et al., 1992). There is a two-way interplay between soma and psyche, and it is important to be careful to not make false assumptions about the direction of effects. In addition, it is necessary to get beyond the crudities of changes in blood flow. Magnetic resonance spectroscopy35 can take things further, and this is likely to be a technique of increasing application in experimental studies, although there are many problems still to be overcome.

MRI does not constitute the only form of functional brain imaging. Further exploration of the use of electrophysiological methods such as magnetoencephalography (MEG)—which has a better time resolution, but a worse spatial resolution than MRI, is likely. It is not clear as yet whether MEG will deliver on its promise. Cautions are required; again, as a result of an awareness that the comparable field of neurometrics failed to deliver what had been thought to be its potential.

Currently, there has been a recrudescence of interest in neuroendocrinology (Carlson & Earls, 1997; Gunnar, 2000; Heim, Ehlert, & Hellhammer, 2000; Heim, Newport, et al., 2000). Both animal and human studies have shown important neuroendocrine effects of stress experiences. Most of this research has been concerned with acute stresses, but neuroendocrinology is beginning to be applied to chronic psychosocial adversities. It's not clear how far this field of research will aid in understanding normal and abnormal developmental processes. The fact that there are neuroendocrine correlates is not in doubt; the question, however, is whether learning more about those correlates will increase understanding of the mechanisms underlying psychological functions. Maybe it will, but I am not sure.

Cognitive psychologists have wanted to claim the whole of mental functioning as their domain (Morton & Frith, 1995). Such presumptuousness needs to be resisted. There is much to be learned from the study of the interconnections between different facets of cognitive functioning. For example, in relation to autism, it will be important to find out how joint attention, theory-of-mind skills, central coherence, and executive planning do or do not reflect the same underlying cognitive skills. There is also much to be learned about the interconnections between those cognitive skills and both emotional and social development. Why, for example, does profoundly depriving institutional rearing seem to lead to both so-called disinhibited attachment patterns and also quasi-autistic behavior (Rutter, Andersen-Wood, et al., 1999; Rutter, Kreppner, et al., 2001)? Why, too, are such quasi-autistic features also found in children with congenital blindness (Hobson, Lee, & Brown, 1999)? What does this tell us about developmental processes, and what are the implications for the syndrome of autism? Answering these questions requires the skills of cognitive psychology, but these must be brought together with parallel skills in the study of socioemotional development and in the investigation of psychosocial experiences.

The field of animal studies has, for the most part, remained rather separate from the study of child development. Of course, there have been pioneers such as Hinde (Hinde & McGinnis, 1977) and Suomi (1997), who have sought to bring the two together but, despite such important exceptions, the two arenas have remained separate from one another. It is important to ask in what areas could animal studies be informa-

tive. There are many, including the investigation of the different forms of developmental programming, the study of sensitizing and steeling effects of stress (and the parallel field of resilience), and the delineation of the effects of psychosocial experiences on the organism.

Attention has been drawn already to the important and puzzling field of gender differences in psychological development. Elucidation of the underlying processes remains a considerable challenge and one that will require the use of research designs different from those ordinarily employed to investigate individual differences. For the most part, it has been found that the risk and protective processes within males and females are broadly comparable; this does not explain, however, why the levels of psychological traits or the frequency of particular disorders are so markedly different between males and females.

FUTURE: RESEARCH, POLICY, AND PRACTICE

The findings on nature, nurture, and development may be used to tentatively look into the future. Attention has been drawn already to the very considerable research challenges that remain ahead. It is apparent that a diversity of causal processes needs to be considered. We must recognize, accept, and seek to understand the anomalies and apparent paradoxes in the findings thus far available, which will require individual creativity and innovation with respect to both concepts and research strategies. Most important, it will require a bringing together of genetics, environmental studies, and developmental investigations. The three fields have remained, for the most part, distressingly separate up until to now, and it is crucially important that they become much better integrated. For example, both genetic and psychosocial research will benefit from a focus on gene–environment correlations and interactions. Similarly, the developmental study of psychopathological progressions needs to use genetic designs to investigate nature–nurture interplay. In these connections, there is much to be gained by bringing together studies of normal and abnormal development. The field of developmental psychopathology is one that has much to offer with respect to the investigation of nature–nurture interplay in developmental processes and in the two-way flow of understanding from the normal to the abnormal and vice versa (Rutter & Sroufe, 2000).

What about implications for policy and practice? In seeking to answer this question, it is necessary that the magnitude of the challenge is accepted. Over the course of the last 50 years, there have been tremendous improvements in the physical health of children and in the life expectancy of adults. It is chastening to realize that there have not been parallel improvements in psychological functioning or mental health (Rutter & Smith, 1995). On the contrary, psychosocial disorders in young people have tended to increase in frequency over the last half century. Why has this been so? I would argue that this has to be an answerable question. If we had a proper understanding of why society has been so spectacularly successful in making things psychologically worse for children and young people, we might have a better idea as to how we can make things better in the future. To succeed in that gargantuan task, use of a diverse range of research strategies is necessary. The answers will not come from genetic research on its own, or from environmental studies, or developmental investigations; the combination of the three might do much, however. It will be necessary to recognize the range of different causal questions that have to be considered. The explanation for individual differences may not be the same as that for differences in the level of a trait or the frequency of disorder.

Effective interventions with respect to either prevention or treatment are not necessarily dependent on understanding basic causal processes but, clearly, an understanding of causal mechanisms is likely to be helpful. Although it is true that all societies have been slow in taking effective action to put into practice knowledge that is already available, it is important that we are realistic about how limited our knowledge is. One of my favorite American sayings is: "It ain't ignorance that does the harm, it's knowing so many things that ain't so." This concern is most relevant with regard to seeking policy and practice implications that derive from basic science. Of course, it is important to act promptly and expeditiously when what is needed is apparent; however, caution should be taken in jumping too readily onto the bandwagons of whatever happens to be the prevailing enthusiasm of the moment. Psychology as a whole, and child development in particular, gains its strength from its importance as an applied science. We must never lose sight of that (Rutter & Yule, in press), which means retaining a broad view of the types of research that are going to be rewarding, and ensuring that we do not avoid directing attention to policy and practice implications simply because it is so difficult to be sure of what is needed. Let us question, but let us study in rigorous fashion, using a creative approach to research strategies; and let us throughout make sure that attention is paid to questions of policy and practice, but also that practical applications of research findings are studied with the same rigorous scrutiny as that used in basic science itself.

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