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Will Future Forensic Assessment Be Neurobiologic?

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NOTE: At the time of publication, author Adrian Raine was affiliated with the University of Southern California. Effective July 1, 2007, he will be a faculty member in the Department of Criminology and the Department of Psychiatry at the University of Pennsylvania.

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Abstract
During the past 2 decades, research on the role of biologic factors in antisocial behavior has made vast progress. This article discusses recent findings and their possible implications for future forensic assessment and treatment. In addition, some relevant philosophical, ethical, and political questions are brought forward.

Comments
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During the past 2 decades, research on the role of biologic factors in antisocial behavior has made great progress. Delinquency, subtypes of aggressive behavior, and psychopathy are just a few of the behavioral constructs that have been associated with biologic parameters [1]. Moreover, some of the observed associations have now been investigated in longitudinal studies, uncovering biologic factors that predispose to antisocial behavior. Findings of these studies suggest that biologic factors are particularly involved in the shaping and development of behavior at a young age, that is, in children and adolescents. At the same time, biosocial models are being developed that incorporate both biologic and social factors, reflecting the assumption that both types of factors interact in a complex fashion to influence the development and persistence of antisocial behavior [2,3]. Current research and influential theories deriving from it shy away from biologic determinism but do stress the need to take into account and study biology as one of the important correlates of antisocial behavior.

The accumulating evidence for a link between biologic factors and antisocial behavior makes timely a discussion of the repercussions that these findings may have on future clinical practice. Such a discussion is relevant for the general juvenile mental health service, which spends a substantial percentage of its time and budget dealing with children and adolescents displaying antisocial behavior. The field of child and adolescent forensic psychiatry, in particular, deals primarily with a population whose psychiatric problems are both of an antisocial nature and still in development. The main purpose of this article is to relate findings from

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biologic research to the core activity of practitioners involved in forensic assessment in juvenile justice settings.

Forensic assessment has been conceptualized as consisting of four distinct components: (1) diagnostic identification, (2) providing treatment options, (3) assessing risk, and (4) evaluating treatment [4]. As discussed elsewhere in this issue, although psychosocial research has provided valuable tools for assessment, the specificity and effectiveness of all four of these aspects can be increased. This article discusses why improving the knowledge of the biologic underpinnings of antisocial behavior and implementing findings from biologic studies in assessment strategies may be one of the ways to accomplish this improvement [1,5]. Although it may be too early to draw definite conclusions on how neurobiologic insights will influence future forensic psychiatric assessment, the authors aim to initiate discussion and to develop ideas related to the provocative question posed in the title of this article.

First, the article briefly reviews the current literature, focusing on three important subfields of biologic research: genetics, psychophysiology/neuroendocrinology, and brain imaging. For each subfield, the authors discuss biologic correlates of antisocial behavior and specific interactions between biologic factors and social factors. Second, the authors evaluate how the reported findings from the reviewed literature may relate to each of the four specific aspects of forensic assessment. Third, the authors address some relevant philosophical, ethical, and political questions that inevitably arise when in a discussion of the biology of antisocial behavior. Finally, the authors discuss the agenda for the coming decade: what should be done to extend knowledge, to start implementing new knowledge in forensic assessment, and to adjust intervention strategies accordingly.

A brief review of the literature

Fig. 1 provides a basic model that can serve as a heuristic guide for the following review of some of the main subfields of biologic research. Although inevitably overly simplistic, the model highlights the key influences of genetic and environmental processes in giving rise to social and biologic risk factors that both individually and interactively predispose to antisocial behavior. In addition, it incorporates the idea that both biology and environment can constitute protective factors as well. Finally, the model suggests that, once antisocial behavior is subject to forensic assessment, all underlying factors may be of value in informing the clinical practitioner.

Genetics

Twin studies, adoptive studies, studies in twins reared apart, and molecular genetic studies clearly support the notion that there are genetic influences on antisocial and aggressive behavior [1,6,7]. Still, heritability estimates (ie, the

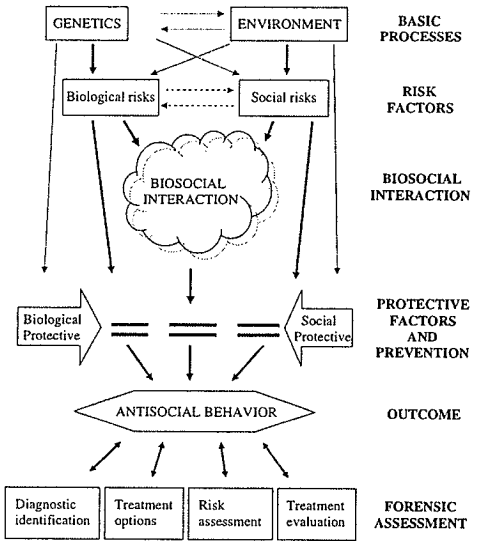

Fig. 1. Heuristic biosocial model of antisocial behavior as applied to forensic assessment. (*Adapted from* Raine A, Brennan P, Farrington DP. Biosocial bases of violence: conceptual and theoretical issues. In: Raine A, Brennan PA, Farrington DP, et al, editors. Biosocial bases of violence. New York: Plenum; 1997. p. 15; with permission.)

magnitude of genetic influences) vary largely among studies [8]. Significant progress in the understanding of these two issues and of the mechanisms through which genes exert their effect on antisocial behavior is likely to be made in the near future for three main reasons.

First, researchers have started to disentangle which distinct subtypes and aspects of antisocial behavior are particularly subject to genetic influence. For example, genetic influences were suggested to be greater for life-course–persistent antisocial behavior than for adolescence-limited antisocial behavior [9] and greater for aggressive antisocial behavior than for nonaggressive antisocial behavior [10].

Second, investigators have started to study associations between specific genes and antisocial behavior. As a result of technological advances, a large number of genetic markers are now available for studying DNA polymorphisms, and new laboratory techniques allow rapid genotyping, the process of identifying which alleles are present for any given marker for a particular person. In general medical research, an increasing number of genes are being identified for specific genetic syndromes. With respect to antisocial behavior, Brunner and colleagues [11] reported a single-gene mutation in the gene encoding the neurotransmitter-metabolizing enzyme monoamine oxidase A (MAOA) in an extended Dutch family in which multiple members exhibited violent criminal behavior. In psychiatric research such isolated mutations are rare, however [12], and it is clearly not plausible to consider them major determinants of multifactorial conditions such as antisocial behavior. Indeed, the precision of today's genetic research techniques makes it increasingly apparent that multiple genes are simultaneously involved in creating susceptibility for antisocial behavior.

Third, investigators have started to acknowledge the interplay between genetics and the environment; that is, whether genetic susceptibility leads to antisocial behavior may depend on the influence of environmental factors. Just as a genetic susceptibility for lung cancer may result in disease only after a person smokes cigarettes, a genetic susceptibility for antisocial behavior may remain latent in the absence of adverse environmental factors such as harsh parenting or living in a criminal neighborhood. For a person with both a genetic risk factor and an environmental risk factor for antisocial behavior, the actual risk for developing antisocial behavior may be far more than just the sum of the two risks [13,14].

An illustrative example, incorporating both the influence of a specific gene and its interaction with the environment in relation to antisocial behavior, is a recent, highly important and influential study by Caspi and colleagues [15]. A functional polymorphism in the gene encoding MAOA was studied in large sample of male children in New Zealand from birth to adulthood. Maltreated children who had a genotype conferring high levels of MAOA expression were found to be less likely to develop antisocial problems than maltreated children who had a genotype conferring low levels of MAOA expression. These findings provide evidence that specific genotypes can moderate children's sensitivity to environmental insults and may partly explain why not all victims of maltreatment grow up to victimize others. The recently increased interest in this kind of biosocial interaction is reflected in the fact that the findings of this study have already been replicated in humans [16] and in rhesus monkeys [17], although one human study did not find the same effect [18].

An interesting interaction effect of a different kind is imbedded in the social-push theory. Under this perspective, when an antisocial child lacks social factors that "push" or predispose him or her to antisocial behavior, biologic factors may more likely explain antisocial behavior [2,19]. In contrast, social causes of criminal behavior may be more important explanations of antisociality in those exposed to adverse early home conditions. This is not to say that antisocial children from adverse home backgrounds will never evidence biologic risk factors for antisocial and violent behavior, clearly, they will. Instead, the argument is that in such situations the link between antisocial behavior and biologic risk

factors will be weaker than in antisocial children from benign social backgrounds, because the social causes of crime camouflage the biologic contribution. Conversely, in antisocial children from benign home backgrounds, the "noise" created by social influences on antisocial behavior is minimized, allowing the relationship between biology and antisocial behavior to shine through. Evidence supporting this theory comes from studies in various subfields of research. Within the field of genetic research, Christiansen [20] in a Danish sample of twins found heritability for crime was strikingly greater in those from high socioeconomic backgrounds and those who were rural born.

Exciting progress is being made in the knowledge concerning genetic contributions to antisocial behavior and the interplay of genetic factors with the environment. The exact mechanisms through which genetic factors lead to antisocial behavior, are not yet well understood, however. One probable important pathway is that genetic factors influence biologic factors, such as arousal and hormonal levels, as well as specific aspects of brain functioning, which in turn influence behavior. Therefore, studying such parameters is important to improve the understanding of the biologic mechanisms underlying antisocial behavior.

Psychophysiology and neuroendocrinology

A number of psychophysiologic and neuroendocrinologic correlates of aggressive, antisocial, and violent behavior have been reported [1,21–24]. For example antisocial behavior has been related to low serotonin [25], high testosterone [26], and low epinephrine [27], although findings have not always been consistent. To illustrate how studying biologic factors in this subfield may contribute to the understanding of which factors correlate with antisocial behavior and of the underlying mechanisms, a specific subgroup of psychophysiologic and neuroendocrinologic factors—those related to arousal—is discussed here.

The arousal theory postulates that low levels of arousal are related to antisocial behavior. Two explanations have been put forward for this assumption. First, the sensation-seeking theory argues that low arousal represents an unpleasant physiologic state. As such, antisocial behavior is viewed as a mode of sensation seeking, which is displayed to increase arousal levels to an optimal or normal level [28–30]. Second, the fearlessness theory argues that low levels of arousal (eg, as measured during mildly stressful psychophysiologic test sessions) are markers of low levels of fear [1,30]. For example, fearless individuals (such as bomb disposal experts who have been decorated for their bravery) were found to have particularly low heart rates and reactivity [31]. Antisocial and violent behavior (eg, fights and assaults) is considered to require a degree of fearlessness to execute, and a lack of fear of socializing punishments in early childhood may contribute to disturbed fear conditioning and lack of conscience development [1]. For a more extensive overview of the underlying theoretical framework see Raine [1,2].

The best-studied biologic parameter of arousal is heart rate, a measure of autonomic nervous system activity. Low heart rate is the most frequently replicated biologic correlate of antisocial behavior in children and adolescents [32]. Low heart rate has repeatedly been shown to predict antisocial behavior, opposing the notion that a delinquent way of life may have caused low heart rate [33]. For example, one study showed that a low resting heart rate as early as age 3 years relates to aggressive behavior at age 11 years [34]. An important feature of the relationship is its diagnostic specificity, because conduct disorder seems to be the only psychiatric disorder to have been linked consistently to low heart rate [32].

Although a low heart rate has been found to be a predictor of violence independent of other social risk factors [35], there is accumulating evidence a low heart rate, like the genetic susceptibility as described previously, interacts with social factors in relation to antisocial behavior. For example, boys who have low resting heart rates are more likely to become violent adult offenders if they also have a poor relationship with their parent and if they come from a large family [35]. Furthermore, boys who have a low heart rate are especially likely to be rated as aggressive by their teachers if their mother was a teenage parent, if they come from a family of low socioeconomic status, or if they were separated from a parent by age 10 years [35]. Studies of arousal also support the social-push perspective. Although the resting heart rate level is generally lower in antisocial individuals, a low resting heart rate is a particularly strong characteristic of antisocial individuals from higher social classes [34,36].

In line with findings from studies on heart rate, other direct and indirect parameters of arousal, including resting electroencephalogram [37] and skin conductance activity [38,39], have been related to antisocial behavior. An interesting and increasingly investigated neuroendocrinologic parameter related to arousal is cortisol, the final product of the hypothalamus-pituitary-adrenal (HPA) axis. Together, the autonomic nervous system and the HPA axis constitute the two most important arousal-regulating biologic systems. In line with the low-arousal theory, several studies have found low basal cortisol levels to be associated with antisocial behavior in clinically referred, at-risk, and general population samples of children and adolescents [40,41] Also, blunted cortisol responsivity to stress has been found in antisocial children and adolescents [42]. One study to date investigated the effect of cortisol levels on future antisocial behavior and found low cortisol levels at age 10 to 12 years to predict aggression at age 15 to 17 years [43]. So far, only one study has investigated how cortisol levels interact with social factors in relation to antisocial behavior. Scarpa and colleagues [44] found that high cortisol after a stressor was associated with aggression in victims of community violence but not in nonvictims.

In summary, this subfield of research is revealing biologic correlates of antisocial behavior and also aids the understanding of the underlying mechanisms. One other method of research, direct brain functioning, is likely to provide important additional information about the underlying mechanisms.

Brain imaging

Brain imaging is a growing and increasingly influential subarea of biologic research on antisocial behavior. Several imaging techniques (eg, MRI, functional MRI [fMRI], positron emission tomography, and single photon emission [CT]) are now in wide use. During the last decade, these techniques, particularly MRI and fMRI, have also been adjusted for use in children and adolescents. The predominant finding in neuroimaging studies of adults is that violent offenders have anatomic or functional deficits in the anterior regions of the brain, particularly the prefrontal region [45]. These studies have covered a substantial variety of samples (eg, murderers, violent schizophrenics, drug-abusing psychopaths, community samples of subjects who have antisocial personality disorder) and measures of frontal functioning (blood flow, glucose, *N*-acetyl aspartate), but sample sizes have generally been small. That most of them observe anterior frontal deficits in association with violent, aggressive, antisocial behavior suggests that frontal dysfunction may be related to generalized antisocial and violent behavior. Prefrontal deficits could lead to antisocial behavior through at least three routes: (1) through a disability to reason and to take appropriate decisions in risky situations [46]; (2) through poor fear conditioning and stress responsivity and thereby poor consciousness development [1,47]; or (3) by lowered arousal levels [48] which, as discussed earlier, can facilitate sensation-seeking and fearless forms of antisocial behavior.

The specific subregions of the prefrontal cortex that are structurally or functionally impaired in antisocial and aggressive individuals are still open to question. Findings from studies investigating damage to the prefrontal cortex in civilians [49] and in soldiers [50] implicate the ventromedial and orbitofrontal subregions. Alternatively, impairments to the dorsolateral region, which is critically involved in cognitive flexibility and response perseveration, cannot be ruled out, because recidivistic antisocial behavior can be conceptualized as perseverative, unmodifiable behavior in the face of a repeatedly punished response.

For long time, evidence for an association between prefrontal deficits and antisocial behavior in children and adolescents has been available from neuropsychologic studies revealing executive functioning deficits in antisocial children [51] and studies showing associations between prefrontal deficits and antisocial behavior after head injury [52,53]. In the twenty-first century imaging studies have started to provide the first, albeit preliminary, evidence for structural and functional brain abnormalities in antisocial children and adolescents. Preliminary studies using MRI [54] and fMRI [55] in small samples found deficits in children and adolescents who had conduct disorder similar to those in antisocial adults.

Again, the biologic correlates of antisocial behavior found in brain-imaging research are likely to be even more informative when interactions with environmental factors are taken into account [56]. For example, one fMRI study [57] showed that a biologic risk factor (initial right hemisphere dysfunction), when

combined with a psychosocial risk factor (severe early physical abuse), predisposed to serious violence.

In conclusion, brain-imaging techniques have started to provide evidence linking brain deficits with antisocial behavior. More studies are needed to reveal which specific subtypes of antisocial behavior are related to which particular brain dysfunctions. Such research should include samples of juveniles and adults.

How do these findings relate to specific aspects of forensic assessment?

As mentioned previously, forensic assessment comprises (1) diagnostic identification, (2) providing treatment options, (3) assessing risk, and (4) evaluating treatment [4]. Some of the important current literature on the biologic factors of antisocial behavior have been reviewed. The question remains: how do findings from the literature relate to these four aspects of forensic assessment? Despite recent progress, major lacunae still exist in the knowledge of the relationship between biology and antisocial behavior. Moreover, the translation of knowledge from correlational and risk research to clinical practice must be undertaken with prudence and due circumspection. Nevertheless, it is important to start studying the future possibilities for biology to inform forensic child and adolescent psychiatry practice. As biosocial models begin to reveal the mechanisms by which biologic and social processes influence the development of antisocial behavior, both types of process may become of value for forensic assessment (see Fig. 1).

Diagnostic identification

Biologic factors may be useful in the process of diagnostic identification for several reasons. First, they may be important in extending the available range of diagnostic assessment possibilities. Currently, some psychiatric dysfunctions are extremely difficult to evaluate. For example, callous and unemotional traits have proven to be hard to assess in an interview or with pencil-and-paper questionnaires. Biologic parameters may be helpful in this respect; for example, callous and unemotional traits have been related to blunted heart rate reactivity [24]. Furthermore, brain-imaging research is beginning to identify the structural and functional correlates of pathologic lying and malingering that, at least in theory, could have implications for forensic assessment in this area [58,59]. Enlarging the range of current diagnostic possibilities by testing for neurobiologic functioning may help identify important psychobiologic deficits that are currently difficult to assess.

Second, specificity of diagnostic assessment may be enhanced when biologic factors are taken into account. It is widely accepted that psychiatric disorders in general, and hence externalizing disorders, are etiologically heterogeneous. Presently, the heterogeneity of patient groups hinders research, assessment, and treatment in psychiatry; all are likely to be more effective when based on a more

homogeneous patient selection. Using biology to define subgroups of patients may be one of the ways to arrive at such homogeneity. For example, with respect to aggression, researchers in neurobiology are attempting to disentangle different subtypes of aggression (eg, reactive versus proactive) based on neurobiologic profiles. Eventually, uncovering underlying biologic mechanisms may even result in revisions of the diagnostic classification of some ranges of pathologic behavior.

Increasing the range of diagnostic tools and their specificity is not just an academic exercise but is likely to be of particular relevance for the three other aspects of forensic assessment also.

Providing treatment options

The improvements in diagnostic identification that may result from the increasing knowledge of the relationship between biology and behavior may simultaneously reveal means to enhance the specificity and effectiveness of current treatment options. Moreover, improved diagnostic identification may lead to new intervention approaches.

First, improving the knowledge about the biologic etiologic factors of antisocial behavior and incorporating these factors in forensic assessment may help direct specific interventions to specific subgroups of patients. In many subfields of somatic clinical practice, biologic markers already are standard determinants of intervention. For example, in cancer treatment, somatic markers are used to choose the most effective chemotherapeutic agent. In psychiatry, researchers have started to investigate biologic markers as predictors for treatment outcome. For example, in depressed patients, pretreatment baseline prolactine levels have been shown to predict response to antidepressant treatment [60], suggesting that subtyping specific patient groups based on this biologic profile can improve effectiveness of treatment.

Improved diagnostic identification may be relevant for other modes of treatment as well as for pharmacologic treatment programs. Preliminary evidence for this assumption comes from a study by Van de Wiel and colleagues [61], who studied cortisol responsivity during stress in 22 clinically referred behavior-disordered children before psychotherapeutic treatment. They found that low cortisol responsivity during stress predicted poor treatment outcome. The subgroup of children with this biologic profile might need different forms of treatment from those with a strong cortisol response to stress.

Second, new treatment possibilities may arise from biologic and biosocial studies. Influencing a biologic factor that is related to antisocial behavior may in turn modulate antisocial behavior. For example, as discussed earlier, low arousal has been related to antisocial behavior. There is evidence that stimulants (eg, methylphenidate) both increase arousal and reduce aggressive behavior [62]. Progress in pharmacologic treatment possibilities may be established by improving the knowledge about the actual underlying biologic deficits that may be targeted.

Taking biologic vulnerabilities into account in understanding juvenile antisocial behavior can also lead to new approaches for nonpharmacologic interventions. For example, there is some preliminary evidence for the possible efficacy of using biofeedback to increase physiologic arousal in hyperactive children [63]. With respect to HPA activity, preliminary evidence for the potential of nonpharmacologic programs to alter biologic vulnerability for antisocial behavior has been provided by Fisher and Stoolmiller [64] in a study evaluating a foster care intervention program. A group of aggressive juveniles were found to have a flattened diurnal pattern of cortisol levels before entering the program. After the intervention, diurnal cortisol patterns were found to be more normal, with high cortisol levels in the morning and a decrease during the day, and aggression levels had diminished. Additional indirect evidence for this assumption comes from prevention studies. For example, there is initial evidence that positive environmental manipulations are capable of both producing long-term shifts in arousal and psychophysiologic information processing as well as adult criminal behavior. In one study, children matched for early psychophysiologic functioning were randomly assigned to experimental and control conditions. The experimental condition consisted of a program in which physical exercise and nutritional and educational enrichment was provided from age 3 to 5 years. This program resulted in increased psychophysiologic arousal and orienting at age 11 years and reduced crime at age 23 years as compared with the control group [65,66].

In summary, incorporating components aimed at understanding and tackling the biologic basis of antisocial behavior in forensic assessment may extend the range of treatment options and improve their specificity and effectiveness.

Risk assessment

As with treatment options, risk taxation may be influenced by knowledge of biologic correlates of behavior. A certain biologic profile may be related to the risk of recidivism and predict treatment outcome. No studies to date have investigated this hypothesis, but indirect preliminary evidence can be found in the literature. For example, in a longitudinal study of the recurrence of depression after treatment, cortisol levels were measured after remittance of a depressive episode. Heightened cortisol levels were found to predict a new episode of depression. In another study, Prichep and colleagues [67] distinguished two separate subgroups of cocaine-dependent males on the basis of a qualitative electroencephalogram. By using this biologic typology, they were able to the predict relapse rate after treatment. In a similar fashion, biologic parameters may be useful in predicting reoccurrence of antisocial behavior. Still, studies investigating this hypothesis are currently lacking.

Treatment evaluation

The last aspect of forensic assessment that may be informed by biologic factors is treatment evaluation. When assessing a certain biologic profile that is

correlated with behavioral problems before treatment, investigating this same biologic profile again after treatment may be useful as a measure of treatment outcome. As discussed previously, preliminary results of a study by Fisher and Stoolmiller [64] suggested that successfully diminishing aggressive behavior by means of a foster care intervention program coincided with normalization of diurnal cortisol patterns. Cortisol levels may be a parameter that could inform practitioners concerning treatment efficacy. Again, no studies to date have investigated the potential of biologic parameters to evaluate treatment outcome within forensic psychiatry.

In summary, although still largely hypothetical, the first evidence from studies in general medicine and other fields of psychiatry support the possibility that biologic parameters may also be useful for forensic psychiatric assessment. Obviously, this hypothesis requires further testing, and practical issues must be addressed when considering incorporating biologic factors in forensic assessment. For example, some of the biologic factors discussed here (eg, brain imaging) are clearly difficult and expensive to assess. Others are fairly simple, quick, and cost-efficient: most genetic tests only require a swab to obtain some cells from the mouth, heart rate can be measured by taking the pulse by hand or with a simple chronometer, and cortisol and several other hormones can be analyzed noninvasively and reliably from saliva. Although it is too early to reach firm conclusions, new studies that specifically test hypotheses concerning the mechanisms by which biologic factors are related to specific aspects of forensic assessment are both feasible and warranted.

Philosophical, ethical, and political considerations

Biologic research of antisocial behavior has a history of evoking passionate debate on philosophical, ethical, and political issues surrounding it. Although they are not the main focus of this article, the authors consider it important to address briefly a few relevant issues. New findings in the growing field of neurobiologic research challenge the current way of conceptualizing antisocial behavior and force consideration of some important questions. For example, now that prefrontal deficits are known to be related to aggression, how should society deal with the cold-blooded murderer who, years earlier, had a car accident damaging crucial parts of the frontal lobe? What repercussions should this knowledge of causality have on the concept of free will and judicial handling? In the future it may be possible to calculate a child's risk of becoming severely violent by adding up the child's gene profile, brain deficits caused by maternal smoking, low cortisol responsivity, and underactive prefrontal cortex—or by scanning the child's genes. Could such a person be forced into some kind of treatment program when this risk reaches a certain limit? If a juvenile in a psychiatric or justice facility has such a risk profile, does this profile influence decisions as to whether the child can return to the society?

Such questions, inspired by the increased interest and progress in biologic psychiatric research, have given rise to a lively philosophical debate. Although elaborating on philosophical theories is beyond the bounds of this article, the authors briefly discuss two issues. First, like scientific research models, philosophical models have been proposed for combining biologic and social perspectives in research. For example, Kendler [68] has advocated explanatory pluralism: hypothetically, by using multiple mutually informative perspectives differing in levels of abstraction, scientific research can provide complementary kinds of understanding. This author argues for a kind of explanatory pluralism, called "integrative pluralism" [69]; by building bridges between etiologic models but avoiding large theoretical frameworks, science may be most successful in uncovering mechanisms underlying mind and behavior. Such a philosophic structure is being provided by combining biologic factors and social factors within psychiatric research.

A philosophical issue that is more specifically linked with forensic psychiatry, and which has potential legal consequences, is related to the concept of free will. Although free will is a complex construct, for the present purposes free will is assumed to reflect the assumption that persons have control over their behavior and therefore can choose whether or not to do something. If biologic factors (eg, prefrontal damage) are causally involved in antisocial behavior, could such a biologic deficit constrain free will (eg, by causing impulsive behavior) and thereby reduce responsibility for a given crime? In this view, free will may be a continuous concept: the more severe the biologic deficit, the less free the will. Already there have been legal cases in which defense lawyers, sometimes successfully, have tried to reduce the charges against their clients by arguing that frontal damage, as revealed by brain imaging, caused the client to conduct the crime [70,71]. Still, such assumptions are currently hypothetical, because research on biosocial causal mechanisms of antisocial behavior is in its infancy; and firm conclusions as to whether a certain biologic factor caused a specific act of antisocial behavior cannot be drawn. Even if such mechanisms are further uncovered, there will be difficulties in moving from findings based on groups of offenders in research studies to conclusions about an individual criminal.

In addition to philosophical issues, this field of research has raised ethical questions, often overheard in political debates. Although ethical issues of biologic research have been discussed in a cautious and stimulating manner by researchers [71,72], this discussion has not prevented biologic research from being particularly unpopular with both right- and left-wing politicians. Conservatives worry that biologic research will be used to let vicious offenders go free. Liberals fret that biologic profiles may someday be used preventively to incarcerate an innocent person who has the profile of a violent offender. One important comment on such concerns is that the relationship between biology and complex constructs such as antisocial behavior will never be hardwired and one-directional. In contrast, it will always be probabilistic and reciprocal. A vast number of biologic and environmental factors interact together in relation to behavior, but it is unlikely that behavior can be predicted with 100% accuracy

in the near future. Notably, the important discussion of how society and politics should deal with the knowledge of factors relating to antisocial behavior is as relevant for environmental predictors as for biologic ones.

Moreover, increased knowledge about the factors, including biologic factors, that cause antisocial behavior can help practitioners improve the tools for treatment and prevention of individual antisocial behavior as well as the tools for protecting society. More efficient prevention programs can reduce the number of children and adolescents who are currently being treated or simply incarcerated in costly residential settings, and more specific and effective treatment programs can contribute to handling their often serious psychiatric problems. Society as a whole can benefit, because improving and using the knowledge of biologic risk factors can be expected, at least to a certain degree, to help prevent the occurrence and severity of antisocial behavior. In contrast, ignoring the question of how juvenile antisocial behavior develops and persists will sacrifice the opportunity to decrease the vulnerability to crime and violence of both individuals and society.

Agenda for the coming decade

The answer to the question posed in the title of this article should probably be: no. It is highly unlikely that future forensic assessment will ever be completely neurobiologic. Nevertheless the authors hope they have shown that appreciating the contribution of both biologic and social factors in the shaping of behavior may prove fruitful. Biologic and biosocial research is starting to provide new insights into the backgrounds of antisocial behavior in children and adolescents. Further research is warranted to learn more about which distinct components of antisocial behavior are most strongly related to particular aspects of biology and the exact mechanisms by which biology interacts with the environment in relation to antisocial behavior. Researchers could help extend this knowledge by conducting new studies and remaining cautious and realistic when describing their results. In addition, the help of clinicians is of great importance in facilitating biologic research within their facilities and initiating the study of the possibilities of implementing the results of current and future biologic research in child and adolescent forensic clinical practice. Although provocative, new findings from this field of research may lead clinicians to rethink their approach to antisocial behavior of children and adolescents and help them find new answers to the causes and cures of their behavior while continuing to protect society.

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