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A biology of misfortune

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The world breaks everyone, and afterward many are strong in the broken places.

—Ernest Hemingway, A Farewell to Arms

Over one out of every five children in the United States lives in poverty.[1] Worldwide, the figure is one out of every two children. Ten million children die each year, most of them in impoverished countries in sub-Saharan Africa and South Asia. The experience of growing up in poverty appears to have both short- and long-term negative consequences. Poor children have higher rates of acute and chronic diseases, and may have worse physical and mental health in adulthood. What we are currently seeking to understand is how socioeconomic status affects health. Even after taking into account factors such as medical care, diet and nutrition, social support, and health behavior, studies of health outcomes still generally find a large effect attributable to socioeconomic status.[2] What is it about social class or social stratification in and of itself that is important for health, both during childhood and in adulthood?

In this article, I make three arguments: first, that the negative consequences of social stratification begin in early childhood; second, that these effects operate through neurobiological pathways that are sensitive to stress and adversity; and third, that there is a subgroup of children that because of the way they are predisposed to respond to stress, are particularly prone to be affected by both positive and negative social conditions. I believe that the evidence I will present brings a new sense of the critical importance of the early childhood experience, and may have important implications for public policy.

Social stratification in early childhood

The experience of young children is affected by their social class in many different ways. Figure 1 shows the difference in exposure to stressful circumstances between poor and middle-income children; there is a much higher level of chaos and disarray for the children in poor families, particularly in regard to housing problems and family turmoil. There are also large differences in the everyday lives of children, as

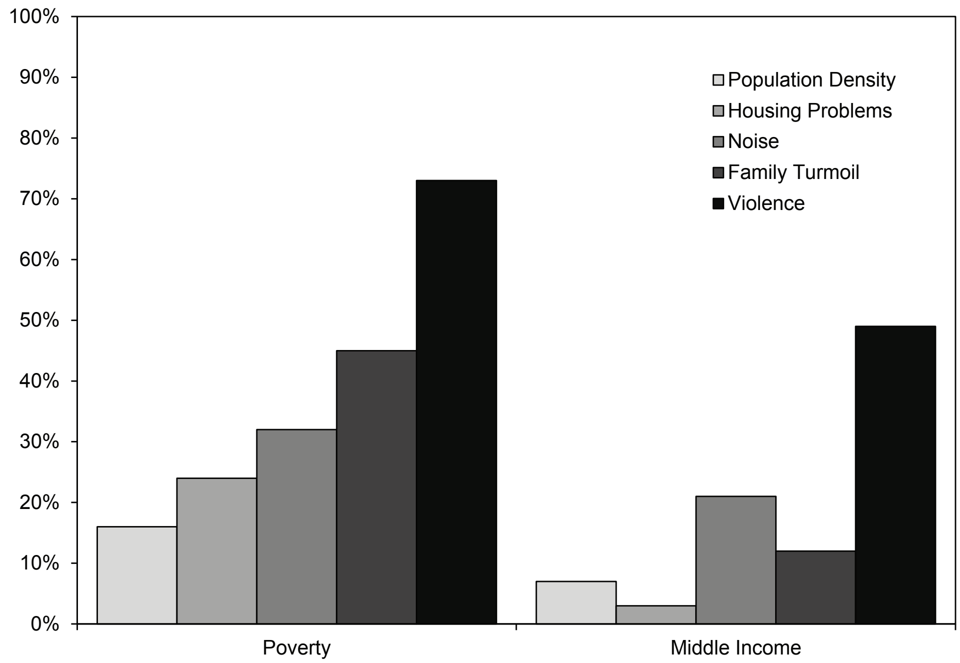

Figure 1. Stressor expoure by socioeconomic status.

Source: G. W. Evans and K. English, "The Environment of Poverty: Multiple Stressor Exposure, Psychophysiological Stress, and Socioemotional Adjustment," Child Development 73, No. 4 (July/August 2002): 1238–1248, Table 1.

demonstrated by an influential study of parent-child communication. Researchers found that children in professional families heard 11 million words in a year, compared to 6 million in working class families, and 3 million in families on welfare. By kindergarten, children from welfare families had heard 32 million fewer words compared to those in professional families.[3] Self-perceived social status is also significantly correlated with health outcomes, even after adjusting for objective measures of social status such as education, occupation, and wealth.[4] This result raises the possibility that the health effects of socioeconomic status may be related to the subjective dimensions of social position.

Naturalistic measures of dominant and subordinate behavior

My colleagues and I have investigated the health implications of perceived social status in a study currently underway in California. We established what any kindergarten teacher would confirm, that young children form social orders within weeks of entering new social groups. We then looked at whether subordinate positions in early peer hierarchies were associated with greater stress, exaggerated reactivity, and stress-related illness.

We observed 29 kindergarten classrooms of approximately 20 children each for a three- to five-week period in order to document social dominance and the class hierarchy. Behaviors recorded included imitation, directing, threat, and physical aggression. Our emerging findings, illustrated in Figure 2, indicate that subordinate social positions are associated with more depression, more classroom inattention, poorer peer relationships, and lower academic competence. The relationship between social position and each of these four outcomes appears to be stronger for boys than for girls. We also find that subordinate rank is interactive with socioeconomic status. Both the highest and lowest levels of prosocial behavior were found among those in the lowest social position, with high socioeconomic status children in that position having the highest levels, and low socioeconomic status children having the lowest levels. We also find that these results are greatly influenced by classroom culture; that is, the extent to which teachers use learner-centered practices that reflect the needs of individual students. For example, in classrooms with the highest level of learner-centered practices, there is almost no relationship between social position and depression, while in classrooms with the lowest levels of these practices, lower social position is associated with much higher levels of teacher-reported depression. In this

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Figure 2. Kindergarten social position and classroom outcomes, for boys and girls.

case, the relationship is stronger for girls than for boys; that is, girls are more sensitive to the effects of their classroom's social climate.

This last effect, of more egalitarian classroom practices eliminating the relationship between position in a social hierarchy and depression, is mirrored in the relationship between parents' social class and literacy levels across countries with differing philosophies and structures. In countries like Northern Ireland, Great Britain, and New Zealand, there is a strong relationship between the two, with literacy levels rising sharply as social class increases. In more egalitarian countries like Sweden and Switzerland, rising social class is associated with smaller increases in literacy. The United States falls in between these extremes, but is closer to the former group than the latter. This result of social position covarying with health, observed in both the microcosm of small classrooms and in cross-national analysis, raises the possibility that there might be something about just knowing that you exist on the lower range of an established hierarchy that has an effect on health, development, and well-being.

Experimental measures of dominant and subordinate behavior

The results from our school observations are reinforced by several experimental measures. Measures of access to a scarce resource were used as a way to measure dominance. In the kindergarten experiment, time spent viewing a video that could only be seen by one person, and only if two other children held down buttons, served as a measure of dominance within small groups of children. A child's position in the social hierarchy, as identified by these experimental measures, correlated as we expected with measures of mental health and cognitive performance. A lower position on the dominance hierarchy corresponded with more anxious and more depressive behaviors, and lower achievement. We also used a biological marker, cortisol production, to measure responsiveness to stress. Again, subordinate kindergarteners responded more strongly to stressful situations than did their more dominant peers.

In both naturalistic and experimental settings, kindergarten children order themselves into hierarchical social groups. Children in subordinate positions had more negative behavioral outcomes, and higher biological reactivity to stressful challenges. These associations were strengthened by low socioeconomic status and weakened by teachers' use of learner-centered practices.

Neurobiological pathways for the consequences of social stratification on health

My second argument is that the health consequences of social class operate through neurobiological circuits that are activated in response to stress and adversity. There are two primary stress response systems in the human brain. One of these governs the production of cortisol, mentioned above, and the other controls the classic fight-or-flight responses to stress. Both of these systems have profound effects on other parts of the body, including the immune, cardiovascular, and gastrointestinal systems. Socioeconomic status is also an

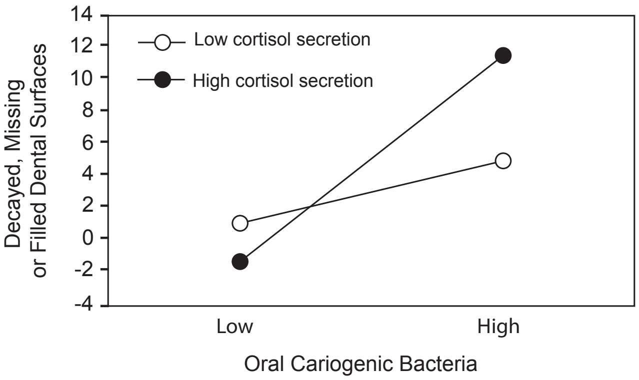

Figure 3. Cariogenic bacteria and tooth decay, by level of cortisol secretion.

Source: W. T. Boyce, P. K. Den Besten, J. Stamperdahl, L. Zhan, Y Jiang, N. E. Adler, and J. D. Featherstone, "Social Inequalities in Childhood Dental Caries: The Convergent Roles of Stress, Bacteria and Disadvantage," *Social Science & Medicine* 71, No. 9 (2010): 1644–1652.

important correlate of reactivity within all of these systems.[5] That is, stress-response pathways tend to be activated at a higher level for children of lower socioeconomic status.

In a recently completed study, we looked at socioeconomic status, stress, and oral health.[6] Dental caries (cavities) are the single most common chronic disease in children, and treatment costs $4.5 billion annually in the United States. Inflammatory changes associated with dental caries may also be related in the long-term to chronic disease in adulthood. There are strong socioeconomic and racial disparities in the incidence of dental caries. Some, but not all, of these disparities are explained by differences in lead and tobacco smoke exposure, diet, and access to fluoridated water. A common belief to account for socioeconomic and racial gaps is that parents of low socioeconomic status neglect their children's dental hygiene.

In our study, we wanted to look at children's exposure to cortisol, an indicator of stress-response which is present in saliva and may have immune-suppressive effects. The problem is that cortisol levels are difficult to measure directly; they fluctuate greatly over the course of a day, and tend to be highest just before waking. Measuring the amount of cortisol in children's saliva at several particular points in time during the day will not reveal total exposure to cortisol over time. The solution to this problem was to collect children's primary (baby) teeth after they come out; cortisol dimineralizes bones and teeth, so a measurement of the density of these teeth serves as a stress indicator for young children.

Of the nearly 100 five-year-old children who provided a tooth for this project, almost half had a filling or decay in at least one primary or secondary tooth (that is, of the teeth remaining in the child's mouth). Lower socioeconomic status was significantly associated with increased financial stress, cariogenic bacteria (the bacteria that cause tooth decay), and dental caries. Figure 3 shows that among those who had high levels of cortisol secretion (which could accelerate bacterial growth and virulence), levels of tooth decay increased steeply as bacteria counts increased, while among those with low levels of cortisol secretion, levels of tooth decay increased only slightly as bacteria counts rose. Both the highest and lowest instances of tooth decay were found among the high-cortisol group, with levels varying according to bacteria counts.

We also found that the thickness of the enamel in the provided teeth varied interactively by level of cortisol reactivity (that is, not simply cortisol secretion, but reactivity to a set of stressful challenges in an experimental setting) and socioeconomic status. Again, both the best and the worst outcomes were found among children who had high cortisol reactivity. For that group, those with low household socioeconomic status had the thinnest dental enamel, while those with high socioeconomic status had the thickest. Children with low cortisol reactivity showed little difference in enamel thickness by socioeconomic status.

Putting these results together, we conclude that oral health disparities are the result, not of negligent dental hygiene, but of two interactive pathways. First, low socioeconomic status children may have earlier and more intensive exposure to cariogenic bacteria; and second, those children may be subject to greater stress, and as a result of stress-response mechanisms, have teeth with thinner enamel that are more susceptible to disease. Most importantly, there appears to be an interaction between the presence of bacteria and the presence of cortisol in the creation of dental caries.

Orchids and dandelions: Stress sensitivity and susceptibility to social conditions

I now turn to my third and final argument, that there is a subgroup of children who are particularly sensitive, and who are thus particularly prone to be affected by both positive and negative social conditions. My colleagues and I have looked in detail at individual difference in immune reactivity to psychological challenge. This is done in an experimental setting, measuring biological reactivity to standardized laboratory stressors. Individuals are then classified into low reactivity and high reactivity groups. An example of the kind of results we have found is shown in Figure 4, looking at occurrence of respiratory illness as a function of stressful life events. Children who were low in reactivity had little change in illness incidence in response to stressors in the lives of their families, but children who were high in reactivity had either the worst outcomes or the best outcomes, depending on the degree to which they were exposed to stress.[7]

Over the last 15 years, we have done a variety of studies using this concept, looking at outcomes including internalizing behavior problems, childhood injuries, and memory of stressful events. Plotting the outcome of interest by a measure of social context, we repeatedly find that individuals with high reactivity have either the best or worst outcomes

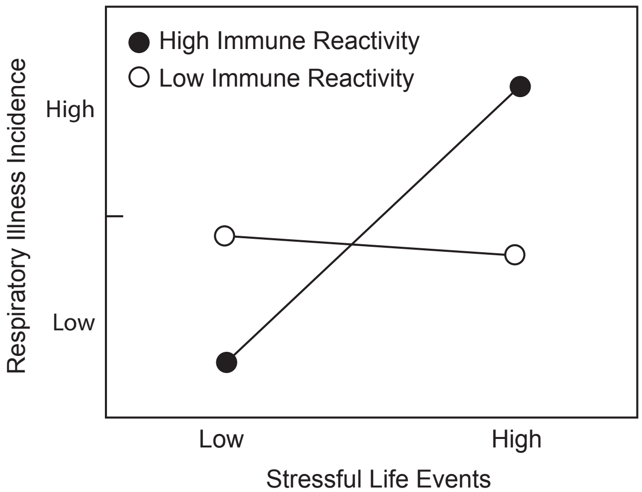

Figure 4. Interaction between environmental stress and immune reactivity in prediction of respiratory illness.

Source: W. T. Boyce, M. Chesney, A. Alkon, J. M. Tschann, S. Adams, B. Chesterman, F. Cohen, P. Kaiser, S. Folkman and D. Wara, "Psychobiologic Reactivity to Stress and Childhood Respiratory Illnesses: Results of Two Prospective Studies," *Psychosomatic Medicine* 57, No. 5 (September 1, 1995): 411–422.

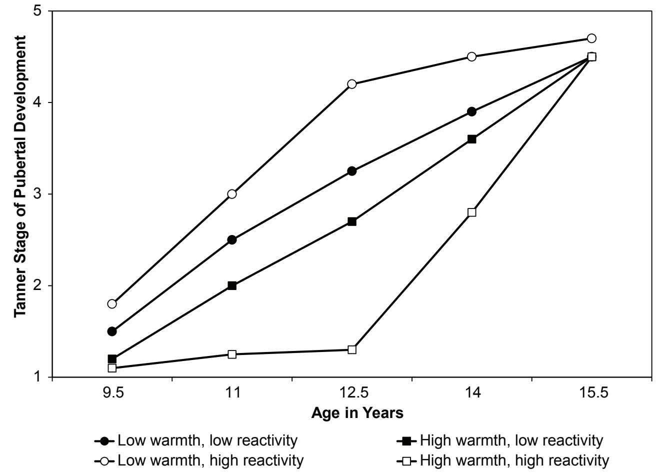

Figure 5. Pubertal development by parental warmth and sympathetic nervous system reactivity.

Source: B. J. Ellis, E. A. Shirtcliff, W. T. Boyce, J. Deardorff, and M. J. Essex, "Quality of Early Family Relationships and the Timing and Tempo of Puberty: Effects Depend on Biological Sensitivity to Context," *Development and Psychopathology* 23 (2011): 85–99.

depending on the social context, while individuals with low reactivity show little difference in outcome as social context varies.

This phenomenon, of high sensitivity to the social environment, turns out to apply not just to disease outcomes, but also to developmental change over time. The age and rate at which children reach puberty have a number of long-term health implications. For example, girls who mature early are at elevated risk for earlier sexual activity and the attendant risks of sexually transmitted infection acquisition and adolescent pregnancy, and may also have increased mortality from cardiovascular disease and breast cancer later in life.[8] Deviations in the rate at which adolescents progress through puberty may also be associated with the development of psychopathology and physical health problems.[9]

A recent study looking at age and the rate at which children reached puberty found an interaction between parental warmth and sympathetic nervous system reactivity. Children were divided into four groups based on whether they were "high" or "low" on parental warmth and sympathetic nervous system reactivity. Across all four groups, pubertal development was generally complete around age 15.5 years, but there were notable differences in the rate and age at which development began. For the children with low sympathetic nervous system reactivity, the level of parental warmth made very little difference in the rate and trajectory of pubertal development. For children with high sympathetic nervous system reactivity, however, the story was very different. Among this group, those with low parental warmth achieved puberty quickly and at an early age, with most development complete by age 12.5. In contrast, the subgroup with high sympathetic nervous system reactivity and high parental warmth tended to develop quite late, with little or no development until age 12.5.[10] Again, both the best and worst outcomes were seen in the group that was predisposed to be most sensitive to their surroundings.

Although the variation in how sensitive children are to their surroundings is really a continuum and not a dichotomy, we do find it useful to have a shorthand way to refer to two kinds of children: a "dandelion child" will thrive in any sort of environment, while an "orchid child" is very sensitive to their environment, with the potential for both extremely positive and extremely negative developmental outcomes. How do we account for these two extremes? We are beginning to believe that this is a conditional genetic adaptation similar to others seen in nature. For example, butterflies of the same species can have very different coloration depending on the temperature and number of daylight hours at the time the butterflies emerge from their pupal stage. This type of change, referred to as epigenetic, is caused by mechanisms other than changes in the underlying DNA sequence, and is heritable. In the case of children, it appears that social environment conditions may be able to activate or deactivate particular genes. A recent longitudinal study provides evidence for this hypothesis, finding that stressors experienced by parents early in a child's life resulted in epigenetic changes observable at adolescence.[11]

Conclusions

Both adult societies and childhood groups self-organize into hierarchical social structures, and these structures result in negative consequences for those on the bottom of the ladder, including subordination, coercion, and scapegoating, in addition to poverty, hunger, and material injustices. Consistent exposure to these factors early in life, and arguably even prenatally, establishes a developmental biology of misfortune involving neurobiologic and epigenetic processes through which one's life course is steered towards diminished health, unrealized developmental potential, and early mortality. I believe that because of these findings, society has an ethical and moral obligation to promote developmental settings for all children in early life that are more egalitarian, more protected, more supportive, and more generous.■

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[1]http://datacenter.kidscount.org/data/acrossstates/Rankings.aspx?ind=43

[2]For example, see M. G. Marmot, H. Bosma, H. Hemingway, E. Brunner, and S. Stansfeld, "Contribution of Job Control and Other Risk Factors to Social Variations in Coronary Heart Disease Incidence," *The Lancet* 350, No. 9073 (July 1997): 235–239.

[3]B. Hart and T. R. Risley, *Meaningful Differences in the Everyday Experience of Young American Children*, (Baltimore, MD: Paul H. Brookes Publishing, 1995).

[4]See, for example, P. Demakakos, J. Nazroo, E. Breeze, and M. Marmot, "Socioeconomic Status and Health: The Role of Subjective Social Status," *Social Science & Medicine* 67, No. 2 (2008): 330–340.

[5]See, for example, S. J. Lupien, S. King, M. J. Meaney, and B. S. McEwen, "Can Poverty Get Under Your Skin? Basal Cortisol Levels and Cognitive Function in Children from Low and High Socioeconomic Status," *Development and Psychopathology* 13, No. 3 (2001): 653–676.

[6]W. T. Boyce, P. K. Den Besten, J. Stamperdahl, L. Zhan, Y Jiang, N. E. Adler, and J. D. Featherstone, "Social Inequalities in Childhood Dental Caries: The Convergent Roles of Stress, Bacteria and Disadvantage," *Social Science & Medicine* 71, No. 9 (2010): 1644–1652.

[7]W. T. Boyce, M. Chesney, A. Alkon, J. M. Tschann, S. Adams, B. Chesterman, F. Cohen, P. Kaiser, S. Folkman, and D. Wara, "Psychobiologic Reactivity to Stress and Childhood Respiratory Illnesses: Results of Two Prospective Studies," *Psychosomatic Medicine* 57, No. 5 (September 1, 1995): 411–422.

[8]See, for example, R. Lakshman, N. G. Forouhi, S. J. Sharp, R. Luben, S. A. Bingham, K. T. Khaw, N. J. Wareham, and K. K. Ong, "Early Age at Menarche Associated with Cardiovascular Disease and Mortality," *The Journal of Clinical Endocrinology & Metabolism* 94, No. 12 (December 2009): 4953–4960.

[9]See, for example, X. Ge, R. D. Conger, and G. H. Elder, Jr., "The Relation between Puberty and Psychological Distress in Adolescent Boys," *Journal of Research on Adolescence* 11, No. 1 (March 2001): 49–70; and B. A. Stoll, L. J. Vatten, and S. Kvinnsland, "Does Early Physical Maturity Influence Breast Cancer Risk?" *Acta Oncologica* 33, No. 2 (1994): 171–176.

[10]B. J. Ellis, E. A. Shirtcliff, W. T. Boyce, J. Deardorff, and M. J. Essex, "Quality of Early Family Relationships and the Timing and Tempo of Puberty: Effects Depend on Biological Sensitivity to Context," *Development and Psychopathology* 23, No. 1 (2011): 85–99.

[11]M. J. Essex, W. T. Boyce, C. Hertzman, L. Lam, J. M. Armstrong, S. M. A. Neumann, and M. S. Kobor, "Epigenetic Vestiges of Early Developmental Adversity: Childhood Stress Exposure and DNA Methylation in Adolescence," *Child Development* September 1, 2011. doi: 10.1111/j.1467-8624.2011.01641.x

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