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Health disparities across the lifespan: Meaning, methods, and mechanisms

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Over the past two decades, exponential growth of empirical research has fueled markedly increased concern about health disparities. In this paper, we show the progression of research on socioeconomic status (SES) and health through several eras. The first era reflected an implicit threshold model of the association of poverty and health. The second era produced evidence for a graded association between SES and health where each improvement in education, income, occupation, or wealth is associated with better health outcomes. Moving from description of the association to exploration of pathways, the third era focused on mechanisms linking SES and health, whereas the fourth era expanded on mechanisms to consider multilevel influences, and a fifth era added a focus on interactions among factors, not just their main effects or contributions as mediators. Questions from earlier eras remain active areas of research, while later eras add depth and complexity.

Keywords: health disparities; gradient; mechanism; pathways; stress

Health disparities have become of central concern in the United States and globally. Populations within the United States experience marked differences in health and longevity. Differences among racial and ethnic groups are pronounced; for example, about twice as many Blacks and Hispanics report being in fair or poor health than do Whites. Differences are even greater by SES; almost five times as many adults in poverty report fair or poor health compared to those with the highest income.[1] Income inequality has increased in the United States over the past 30 years due to differential change in real family income. In 1979, the top 5% of families had average incomes that were 11.4 times larger than that of the bottom 20%; however, by 2005, the ratio had risen to 20.9 times greater.[2] During this period, real income fell slightly for those at the bottom while skyrocketing for those at the top. From the lowest to the highest income quintiles, the changes in income were −1%, 9%, 15%, 25%, and 53%, respectively.[3]

These trends have raised alarm about the impact of a skewed distribution of societal resources on social and physical well-being. Public health officials have called attention to this problem and pledged to reduce it. Healthy People 2010 that was released in January, 2000 and set goals for the health of the United States in the first decade of the 21st century, had two overarching goals: (l) to increase the quality and years of healthy life; and (2) to eliminate health disparities which were defined as "differences that occur by gender, race or ethnicity, education or income, disability, geographic location, or sexual orientation" (p. 11).[4]

A midcourse review of progress toward achievement of Healthy People 2010 goals is sobering. Despite an explosion of research, and increasing life expectancy, significant differences remain along racial and ethnic, and socioeconomic (SES) lines.[5] Progress was measured in 28 focus areas with 467 specific objectives (e.g., increase the proportion of adolescents who participate in daily school physical education, decrease the proportion consuming more than 10% of calories from saturated fat). Disparities in health between racial and ethnic groups

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have lessened for some objectives, but these gains have been partially offset by increases in disparities on other objectives. For 195 objectives and sub-objectives with trend data for racial and ethnic groups, 14 showed increases in disparities and 24 showed decreases. Data on changes in disparities due to education or income are lacking for many Healthy People 2010 objectives but the few available indicators show even more discouraging trends; disparities among educational groups decreased for three objectives or sub-objectives but increased for 14, and there were few changes in disparities for income groups. We are clearly not going to eliminate health disparities by 2010, and there is some question whether we will have reduced them in any meaningful way or if some will actually have increased. This adds urgency to the need to understand how disparities emerge and how they can be eliminated.

Defining health disparities

Although eliminating health disparities is a frequently voiced aspiration, there is little consensus on its definition.[6] Health disparities frequently refer to disparities in health care, including differential access to screening and/or treatment options, or unequal availability of culturally or linguistically knowledgeable and sensitive health personnel. It is also used in the United States to refer to differences in health care or health status among different racial and ethnic groups, whereas in the United Kingdom and European nations it more frequently refers to differences associated with social class and socioeconomic status (SES). Despite their differences, most definitions share a common element of identifying a disparity as a difference in health status between social groups (e.g., socioeconomic, racial/ethnic, gender) that is not only unnecessary and avoidable, but in addition, is considered unfair and unjust.[7] In recent years, the term "health inequities" has been used more frequently, emphasizing the injustice of the difference in health status. Because the definition of health disparities includes the characteristic of injustice, we use the terms "health disparities" and "health inequalities" interchangeably in this volume. In addition, to maintain continuity with our previous work, the former term is primarily used.

In the following papers, we examine differences in health status associated with SES and associated disadvantage, and the biological processes responsible for these outcomes. Socioeconomic deprivation is a key mechanism through which other bases of social disadvantage, particularly those linked to race and ethnicity, result in poorer health status.[8] Health disparities associated with race and ethnicity receive more attention in the United States for a number of reasons, including greater availability of data on racial and ethnic differences in health and receipt of health care services than on social class differences. The United States is unlike most other countries in its failure to collect health statistics regarding social class.[8] As a result, as Isaacs and Schroeder[9] have observed, class is an "ignored determinant" of the nation's health.

Evolution of health disparities research in the United States

Interest in health disparities has grown geometrically over the past 20 years. A primary contributor to this surge is the persistence of health disparities despite improvements in medical care and public health prevention initiatives. The number of studies on disparities associated with SES as well as by race/ethnicity has increased dramatically. Researchers are asking more complex questions, and using more sophisticated approaches and methods. Within the last 20 years, one can identify several distinct eras of work on health disparities associated with SES. New questions addressed in later eras of research did not replace the need for further work on questions posed in prior eras, but often added new complexity and depth to the questions and/or the methods for answering them. The first era used a threshold framework; poverty was conceptualized as a categorical determinant of health. The second era added greater nuance in examining graded associations between health status and socioeconomic resources resulting from higher education, income, and occupational status across the entire SES hierarchy, and began to consider how socioeconomic position intersected with social disadvantage associated with gender and with race/ethnicity. The third era began to identify mechanisms linking SES and health, attempting to discover the intermediate processes accounting for the graded relationship observed in the studies of the second era. The fourth era added the complexity of multilevel effects, such as the independent contribution of neighborhood characteristics above and beyond those of individuals' own socioeconomic

characteristics. And an emerging fifth era is looking at interactions among such factors, not simply their main effects. Such work is looking, for example, at how the impact of individual SES is modified by neighborhood environments.

First era: poverty as threshold

The first era of research occurred before there was an explicit discussion of "health disparities." The strong relationship between SES and health has been observed for centuries and in many countries.[10–12] Earlier observations, conceptual frameworks, and methods of analysis foreshadow the evolution of work on health disparities that has occurred during the last 20 years in the United States, as well as the continuing debate over what lens to use to view the problem.

The importance of socioeconomic conditions for health was explicitly studied in the 19th century. William Farr worked for over 40 years to document the socioeconomic differences in disease in England.[13] In the mid-1800s, Rudolf Virchow[14] identified poverty and unemployment, lack of education, and political disenfranchisement as essential sources of disease. At the end of the century, Durkheim[15] discussed differences in suicide rates as a social rather than individual phenomenon. Friedrich Engels[16] saw poverty and unemployment as fostering ill-health, and placed primary responsibility on the "upstream" force of the political economy of Victorian England. This thread has been carried forward by current day scholars including Doyal,[17] Link & Phelan,[18] Navarro,[19] Townsend,[20] Tesh,[21] and Kreiger,[22] who argue for examination of the societal processes that create the socioeconomic conditions that result in health disparities.

Twentieth century theory and research provided a foundation for studies on the cascade of factors resulting from socioeconomic position and their impact on health. The bio-psycho-social model formulated by George Engels[23] hypothesized that a variety of pathogens, including psychosocial factors such as stressors and life styles, combine to foster disease. This conceptualization provided a framework for multilevel analysis and research on processes such as cumulative risk and allostatic load (see Evans and Kim and McEwen and Gianaros, in this volume). Medical sociologist Aaron Antonovsky[24,25] added another dimension through his exploration of factors that help people to cope successfully with the unavoidable stressors in life. This work developed the concept of "salutogenesis" and emphasized the importance of a "sense of coherence"—comprehending, managing, and seeing meaning. While Antonovsky's work was based on individual functioning, it also provided an intellectual precursor to research on the health-promoting (or, in Antonovsky's words, "salutogenic") aspects of social environments that can mediate or buffer effects of low SES (see Matthews, Gallo, and Taylor, in this volume). At the social level this extends to concepts of social capital and neighborhood cohesion (see Diez Roux and Mair, in this volume).

In the second half of the 20th century, empirical work done by Kitagawa & Hauser[26] examined associations of mortality with both income and education in a nationally representative sample of the U.S. population. This work signaled increased quantitative interest in the relationship between social factors and health. Kitagawa and Hauser found monotonic inverse relationships of income and education with mortality which were independent of one another, and found that the association was stronger for adults age 25–64 than for those over age 65. The Black Report in England[27] documented increasing disparities in mortality by social class despite the establishment of the National Health Service. This unexpected finding was attributed to growing inequality in England over the period examined and the impact of material hardship among the disadvantaged.

With the notable exception of Kitagawa and Hauser, the vast majority of research before the mid-1980s on socioeconomic contributors to health in the United States did not examine income as a continuum but focused on poverty.[28] The most common study design involved a comparison of health status or mortality for individuals whose individual or household income fell below the federal poverty line compared with those who were above this line. The underlying assumption was that a meaningful threshold was crossed when a person moved out of poverty and that differences in morbidity and mortality were due to material deprivation. In this model, increasing income below the poverty line impacts health up to the point where income becomes sufficient to move the individual or family out of poverty, at which point further increases in income have little or no effect on health. The socioeconomic

variables of education or occupational status were not as often studied in this era and this work was not explicitly conceptualized or framed in terms of disparities.

There was also substantial research on racial differences in health in this era. Most of the research documented differences between blacks and whites. There was little examination, however, of the relationship of race and SES or appreciation of the fact that racial prejudice and discriminatory policies relegated a higher proportion of blacks to lower rungs of the SES ladder. Subsequent studies have shown that socioeconomic disadvantage accounts for some, but not all, of the racial differences in health[8,29,30] (see Williams et al., in this volume). In this earlier era, although most studies made either SES or race/ethnicity the primary focus, with only passing attention to adequate measurement and tracking of the other. There was also relatively little research on the health status of other racial and ethnic groups.

Convincing data on the link between poverty and higher mortality fueled interest in the impact of financial resources on health. The few studies that looked above the poverty line found that the influence of socioeconomic position on health continued to operate. These findings suggested that it might not only be extreme material privations associated with poverty that had health effects but other factors associated with SES. These observations did not cohere into a concerted research focus however until late in the century.

Second era: gradients

In response to the empirical work linking SES to health a second era of work arose during the mid-1980s. Although we term this a second era, it is actually the beginning of work undertaken with an explicit framing of "health disparities." The Whitehall studies of civil servants galvanized interest in the power of socioeconomic forces and ushered in this new era.[31–33] The powerful unexpected finding from the first Whitehall Study was that there was a monotonic relationship of occupational grade and health at all levels of the occupational hierarchy. Not only did those at the bottom of the occupational grades have worse health and higher mortality than those above them, but, in addition, improvements in health and longevity were observed at each successive step up the occupational grades, all the way up to the highest level. These findings were particularly notable since they occurred within a population in which all participants were employed and living well above the poverty line. It challenged the assumption of a threshold of income above which increasing resources would not benefit health. The results also challenged the view that social class differences in health resulted solely from material privation, and initiated a debate which became more vocal in the third era

A second aspect of the Whitehall study also helped galvanize interest in health disparities. The glaring problem of lack of universal health care in the United States has been a focus of intense concern and debate for some time. The dominance of this issue suggests an implicit assumption that universal coverage will solve the problem of disparities. Although the Black Report[27] had shown this not to be the case in England, results from the Whitehall studies reinforced those findings. The fact that substantial differences in morbidity and mortality were found across the SES hierarchy despite the availability of health care for all the Whitehall participants, ruled out differential health care as a major factor in determining disparities in mortality.

The powerful findings from the Whitehall studies spurred investigators to see if a similar gradient would be found in the United States. This was challenging to do using existing data sets because most did not have data that were sufficiently detailed to evaluate gradients. As noted earlier, most studies coded people only in terms of whether they were above or below the poverty line. Despite this, a number of papers reported gradients in disease prevalence and mortality rates.[34–36] In addition, Pappas *et al.*[37] demonstrated that the gap in mortality between richer and poorer individuals and between those with more or less education, had increased between l960, when Kitagawa and Hauser did their analysis, and l986. The findings echo the focus in the first era on the importance of poverty, as the steepest drop in mortality occurs as income increases at the very bottom of the income distribution (see Fig. 1). At the same time, mortality continues to drop as income increases even well into higher levels[38] (see Dow and Rehkopf, in this volume).

The studies described earlier demonstrated the SES-health gradient in adults. During this era,

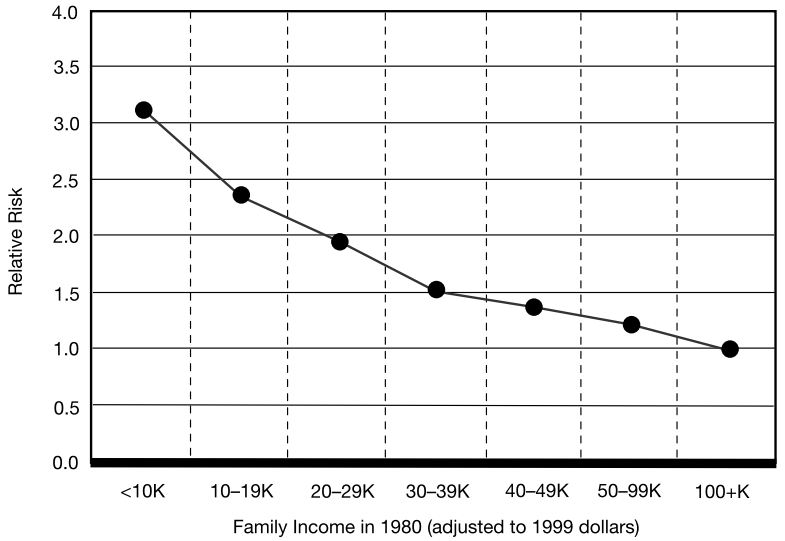

Figure 1. Relative risk of premature death × family income (U.S. population). Age- and sex-adjusted relative risk of dying prior to age 65 based on nine-year mortality data from the National Longitudinal Mortality Survey.

studies also revealed that gradients emerge early in life. The lower the SES of a child's parents, the more likely the child is to experience a number of health problems, including injury, asthma, ear disease, limiting chronic conditions, and physical inactivity[39] (see Cohen *et al.*, in this volume.) The accumulation of social disadvantage is linked to poorer health among children[40,41] (see Evans and Kim, in this volume). Among children in the 1994 and 1995 National Health Interview Survey Disability Supplement, for example, greater accumulation of family indicators of low SES were associated with greater odds that children would not be in very good or excellent health, would have a chronic condition, or would have an activity limitation. Controlling for health insurance did not affect the findings.[42]

Although evidence about gradients among both children and adults emerged primarily in this second era, work continues to establish the strength and shape of the gradient at different ages. The period of life in which health disparities are the greatest is middle adulthood (age 40–65); disparities at this life stage may reflect the cumulative effects of differential exposures associated with socioeconomic disadvantage over the prior lifecourse. Disparities narrow after age 65, although the reasons for this have not been established. Safety nets, including Social Security and Medicare, which become active at this age, may account for some degree of narrowing. Alternately, differential selection of those who have survived to age 65 in populations that have experienced more or less adverse conditions over their lifetime may also contribute to the narrower gap. Although diminished, the gradient does not disappear, however, and has been found in older populations. For example, Minkler *et al.*[43] found a social-class gradient in functional limitations for both men and women between the ages of 55 and 84 (but not beyond), which was present even at the upper rungs of the socioeconomic ladder.

Questions remain about the steepness of the gradient within childhood and adolescence. There is a clear gradient between SES and early fetal and neonatal loss.[44] However, once infants survive this period, socioeconomic differences in health are much smaller. While some report that differences become negligible as children enter adolescence,[45] there are conflicting findings. For example, Case *et al.*[46] found an increasingly steep gradient between family income and health as children get older. One reason for conflicting findings may be the use of different health indicators. The strength and patterning of the gradient differs depending on the outcome being examined. For some health problems, there is an increasingly steep gradient over childhood and adolescence (the cumulative model as reported by Case *et al.*),[46] for other health outcomes, the

gradient decreases (the convergence model, as reported by West).[45] Sample composition and variable calculations can also result in conflicting findings[47,48] (see Cohen *et al.*, in this volume for a further discussion of associated conceptual models).

Research establishing the gradient relationship between SES and health is primarily cross-sectional, and the causal direction cannot be firmly established. Most researchers interpret the association in terms of SES determining health status. However, some researchers have shown that health status also affects SES. Among adults age 50 and older in the Health and Retirement Study, Smith[49] showed that individuals who experienced episodes of poorer health had subsequent drops in income resulting from health care costs and/or reduced involvement in work or early retirement. In additional analyses, Smith[50] showed quantitatively large effects on employment, income, and wealth of new serious health events. He also demonstrated additional effects of early life experiences, showing that better childhood health and family economic environments as reported in adulthood remained significant predictors of better adult health even after controlling for current health and economic status (see Kawachi, in this volume).

The clearest demonstration of the effect of SES on health is in relation to birth outcomes. Infants born to mothers with less education and less income are more likely to experience intrauterine growth restriction, be born prematurely, and have a low birth weight.[51] This disadvantage sets them on trajectories of poorer health, but also of lower adult SES achievement[49] as childhood illness affects academic achievement that, in turn, shapes adult SES.[52] Over the entire lifecourse, as shown in Figure 2, there are reciprocal influences, with SES impacting health and health impacting success in various SES domains (e.g., educational attainment, adult occupation and income, retirement assets).

The second era shone a light on health disparities along the entire socioeconomic hierarchy and across the lifespan. It raised questions about the causal direction and the strength of the gradient at different life stages, and research on these questions continues. At the same time, it raised questions about how these socioeconomic forces result in poorer health. These questions became the basis for a third era of research.

Third era: mechanisms

The central questions of the third era of research revolve around the mechanisms by which SES affects health. What is it about more money, more education, and higher social class that lead to better health? Increased interest in model development in the social sciences, methodological developments from the field of anti-poverty research,[53] and more sophisticated treatment of the moderator–mediator variable distinction[54,55] contributed to this next evolutionary step toward more mechanistic analyses, building on the more descriptive work done in the first two eras. The early explanations for findings of a graded association between SES and health were of two types. Some researchers, for example, Lynch *et al.*,[56] emphasized the importance of material resources; whereas others, for example, Wilkinson,[57] noted the contribution of psychosocial factors. These can be seen as competing explanations, but they are not inherently at odds with one another. The gradient may emerge as the result of both types of variables and their interaction (see Kawachi *et al.*, in this volume, for a

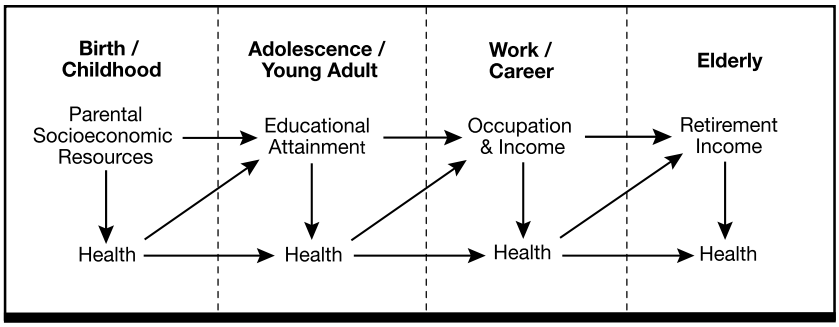

Figure 2. The dynamic relationship between SES and Health.

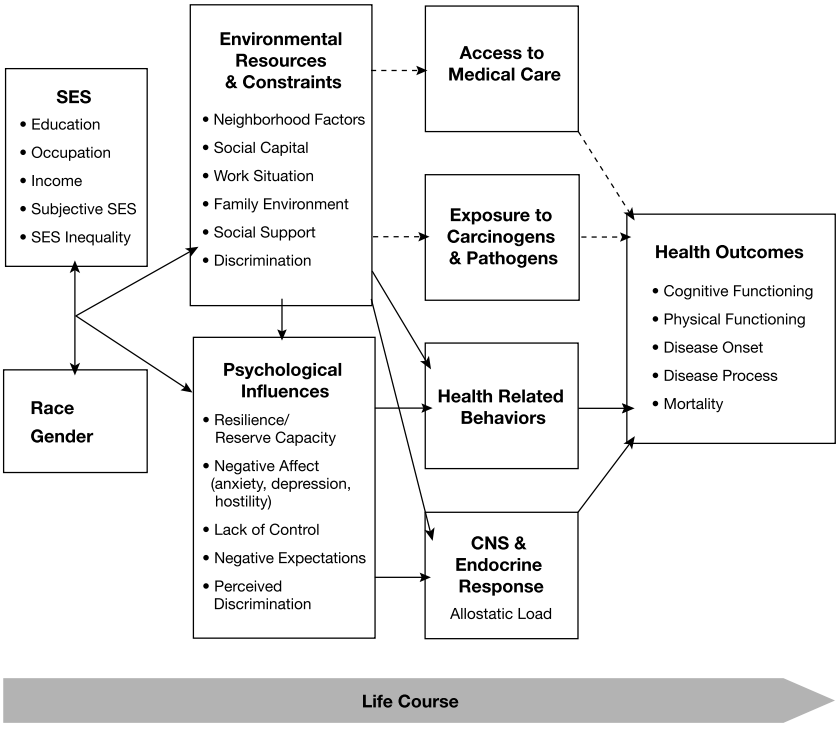

Figure 3. **Pathways linking SES and Health. *Note*: The *solid lines* indicate pathways studied by the MacArthur Network on SES & Health; *dashed lines* indicate pathways of importance which the network did not study.**

fuller discussion). Although it seems likely that material resources would play a particularly important role among those at the bottom of the SES hierarchy, Lachman & Weaver[58] found low SES individuals with a high sense of control showed levels of health and well-being comparable with individuals in higher income groups.

The MacArthur Research Network on SES & Health was established to identify the mechanisms by which those who are disadvantaged on the basis of SES develop poorer health. Investigators from a range of disciplines joined together to address the question "How does socioeconomic status get under the skin?" (see Adler and Stewart on team science, in this volume, for a more detailed account of this process). To frame our research, we first developed a simplified model to depict the major pathways by which SES could influence biological processes in the body (see Fig. 3). The model did not include feedback loops and interaction effects, because at this point identifying pathways without these complicating factors was sufficiently challenging. The examination of interactions awaits the fifth era of research. The papers that follow describe specific psychosocial and biological pathways linking SES and health. Here we briefly touch upon some of the pathways that are often cited as contributing to health disparities, including health care access, environmental exposures, health behaviors, and psychosocial and biological processes associated with stress exposure.

Differential access to health care, as noted earlier, is perhaps the most salient pathway from SES to poor health in the United States, and is certainly the one which has received the most popular and scientific attention. Given the lack of universal coverage, those with less income and in occupations/jobs that do not provide insurance are more likely to be uninsured.[59] A good deal of research has focused on the role of unequal access to health care in the creation of socioeconomic and racial/ethnic health disparities. Andrulis[60] makes a case for the importance of universal health care in reducing health disparities through a select review of studies linking health care access, socioeconomic group, and health consequences. Interventions that provide more

intensive treatment appear particularly effective in diminishing disparities in outcomes. For example, a New Jersey initiative to improve birth outcomes among ethnic minority women found an increase of almost 56 g in mean birth weight and a 3.7% reduction in the likelihood of having a low birth weight infant in response to the program which increased prenatal visits, increased provider reimbursement and provided post-pregnancy follow-up, case coordination and health education.[61] Similarly, socioeconomic disparities in mortality due to hypertension were eliminated in the Hypertension Detection and Follow-up Program where all participants, regardless of SES, were provided comparable levels of care.[62]

In general practice, however, given the features of our current health care system, simple provision of health insurance will not eliminate disparities. For one thing, insurance coverage alone will not assure equal access and use. Travel time, transportation availability and cost, scheduling flexibility, sense of self-efficacy and control, among other factors, all affect individuals' capacities to take advantage of access to medical care. These factors are affected by SES. In addition, our system focuses primarily on medical treatment of diseases, not on their prevention. Overall health and longevity are determined to a greater extent by whether one falls ill rather than by medical care. Inadequacies of health care, including lack of access and poor quality of care, are estimated to account for only about 10% of premature mortality overall.[63] Thus, health disparities would remain even under conditions of universal coverage as has been found in England and other countries with such coverage.

Although not the whole story, health care is still an important pathway. Frenk[64] notes that while it is clear that access to health care will not alone eliminate health disparities, it is reasonable to assume that it may work synergistically with improved social conditions to provide disadvantaged groups with better health outcomes.

Environmental exposures are a second pathway linking SES and health. Environmental hazards and resources are not randomly distributed. Rather, low SES communities are subjected to more hazards and have access to fewer resources to ameliorate their effects. Recognition of the differential placement of environmental hazards like toxic dumps in disadvantaged communities gave rise to the environmental justice movement.[65] The U.S. EPA endorsed environmental justice with the statement that "no group of people, including racial, ethnic or socioeconomic groups should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal environmental programs, and policies.[65] (pp. 7–8)."

Much of the research documenting unequal exposures to chemical and other toxic substances has been done outside of the medical domain and there is limited research on the contribution of environmental exposures to the SES gradient in health.[66] Existing studies document that exposures to such environmental forces as air and water pollution, ambient noise, hazardous waste and toxins such as lead are socially patterned, with lower SES individuals having greater exposure.[66]

As with access to health care, environmental exposures are salient to communities, but may play a limited role in determining health disparities, in part because of their minor role in determining health overall. McGinnis *et al.*[63] estimate that the physical environment contributes only 5% to premature mortality; in comparison they estimate that health behaviors are responsible for 40% of premature mortality.

Health behaviors contribute to higher morbidity related to a range of diseases as well as to mortality. Virtually every health behavior, including smoking, physical inactivity, and unhealthy diets, is patterned by SES. Among the health behaviors, tobacco use accounts for the greatest number of deaths, with approximately 400,000 deaths a year in the United States attributed to smoking.[67] Smoking is detrimental to a number of bodily systems, including respiratory, cardiovascular, and immune systems, resulting in diseases such as COPD, CVD, and various types of cancer. It is not only individuals who smoke who bear the negative health consequences, but also those who live with them. Maternal and paternal cigarette use expose children in the family to second-hand smoke. Such exposure has short-term health effects, such as exacerbating respiratory problems and asthma,[68] as well as setting the stage for diseases which arise later in life.[69] In addition, parents' smoking provides a model which may increase the likelihood that their children will themselves become smokers.[70]

Although 40 years ago smoking was equally prevalent at different levels of SES, today it is more common among those with less education and income. Those of higher SES had more access to compelling evidence on the link between smoking and cancer and cardiovascular disease, and to resources to help them stop smoking. Thus, smoking rates declined far more rapidly at higher SES levels. Differential rates of smoking by SES currently contribute to health disparities. For example, lung cancer previously did not show an SES gradient but as smoking became socially patterned, a gradient has emerged in rates of lung cancer.

SES gradients exist in other health behaviors as well. The growing obesity epidemic, with its association with type 2 diabetes, hypertension, coronary heart disease, stroke, heart failure, and several types of cancer[71–74] is more acute among lower SES populations. Although there are divergent estimates of the impact of overweight and obesity on mortality,[75] epidemiologic studies demonstrate a moderate increase in mortality with overweight and a two- to threefold mortality increase with obesity. Manson *et al.*[75] conclude that quality-adjusted life expectancy at age 18 is reduced by 7.2 years for obese women and 4.4 years for obese men.

Obesity is the result of behaviors involved with diet and exercise that determine the balance of energy intake and expenditure. These behaviors are influenced by external factors such as food industry advertising, the availability of affordable and nutritious food and pleasant recreational areas, and mandated activities such as school physical education programs. Interestingly, while there is an SES gradient in obesity, the gap in rates of obesity by SES is closing somewhat.[76] Rates of obesity are increasing in all segments of the U.S. population, but rising faster now at higher levels of SES. It may be that lower SES individuals were "early responders" to the increasingly obesogenic environment in the United States. As the rest of the population shows the effects of this environment, efforts to reverse the trend may differentially benefit those of higher SES. If so, as with cigarette smoking; we may see the gap increase in the future.

Differential exposure to stress constitutes a fourth pathway between SES and health. This pathway is less obvious than the others, and the magnitude of its impact on premature mortality has not been calculated. Stress is defined and measured in a number of ways. Some research, especially that using an epidemiological approach, focuses on the external threat, or "stressor." This is generally defined as an objective event, which requires change or adaptation by an individual and/or is consensually judged to have negative impact. The research on life events uses such an approach.[77,78] However, observing that not all individuals experience the same event as equivalently threatening, psychologists such as Lazarus and Folkman[79] define stress as a subjective state that emerges when individuals appraise a threat as exceeding their resources to deal with it. Still others define stress in terms of the physiological indicators of activation of the stress response system, including activation of the sympathetic nervous system (or vagal withdrawal) or of the hypothalamic–pituitary–adrenal axis[80] as reflected by changes in blood pressure, heart rate and heart rate variability, skin conductance, and cortisol.

Stress has health effects when it exceeds coping capacities, and especially when it is severe and/or chronic. Some "stress" can be positive, as when a challenge is met and results in a satisfying outcome; such experiences can create a sense of exhilaration, and of mastery and control. If the threat itself cannot be modified but the individual has sufficient social and psychological resources to deal adequately with its emotional impact, stress is negative but not necessarily damaging. In contrast, toxic stress results when an individual is chronically exposed to uncontrollable stressors, such as a chaotic environment, abuse or neglect, in the absence of adequate social or emotional support. Increasing intensity and frequency of stressors interacting with fewer personal and interpersonal resources can contribute to tolerable stress turning into toxic stress. The chronicity and severity of stressors play key roles in moderating the nature and intensity of associated alterations in immunologic parameters[81] and inflammatory processes.[82,83] In addition to direct physiological effects of toxic stress that increase risk for disease, individuals may attempt to cope with these experiences through health-damaging behaviors.

Research linking stress and health is built on a strong foundation of basic research on physiological effects of stress exposure. Much of this research has been laboratory-based or uses animal models. It has provided knowledge of the stress response and the role of stress hormones in regulating the immediate fight or flight response.[84] Stress has been studied less

often in the "real world." Lower SES environments expose individuals to more stressors while simultaneously providing them with fewer resources to deal with these stressors. These environments increase the likelihood of acute stress exposure and also contribute to toxic chronic stress.[85,86]

The stress response is protective in the short term; it allows an immediate reaction to a threat followed by reestablishment of homeostasis. However, when stressors are frequent, over time the constant readjustment of the stress response system may cause dysregulation in multiple bodily systems. Chronic levels of stress have been linked to adverse effects including high blood pressure, susceptibility to infection, the buildup of fat in blood vessels and around the abdomen, and atrophy of brain cells. [87–92] "Allostatic load" provides a useful heuristic model accounting for such changes in response to chronic stress.[93–95] Allostatic load scores reflect how well or poorly the cardiovascular, metabolic, nervous, hormonal and immune systems are functioning. Higher scores indicate greater dysregulation and greater vulnerability to disease and predict subsequent onset of cardiovascular disease and mortality. Several studies have shown that allostatic load scores increase as SES decreases.[96,97] Work to determine the best operationalization for allostatic load continues, but the evidence is growing that it captures biological consequences of stress that may help account for the linkage between socioeconomic disadvantage and a wide array of disease outcomes, and all-cause mortality (see McEwen and Gianaros and Seeman *et al.*, in this volume).

Evidence of allostatic load resulting from chronic stress associated with lower SES is consistent with the view that SES-related exposures contribute to an acceleration of the aging process. Aging is associated with the increasing dysregulation of bodily systems; this natural process appears to accelerate, moving earlier in the lifecourse when individuals are living with greater adversity (see Seeman *et al.*, in this volume). Conversely, a more advantaged life may slow the aging process. Geronimus[98] suggested a similar process of accelerated aging resulting from social disadvantage in relation to birth outcomes, which she termed "weathering." The weathering hypothesis posits that the poorer birth outcomes for African-American women compared to age-matched peers which become more marked as women enter their 20s and 30s reflects earlier health deterioration as a consequence of social exclusion. In a recent study, Geronimus *et al.*[99] found higher allostatic load scores for blacks versus whites in a nationally representative sample, a result especially marked among those aged 35–64.

Recent studies provide preliminary evidence that social disadvantage associated with low SES may accelerate aging at the cellular level as indicated by the length of telomeres. Telomeres, DNA repeat sequences at the tips of chromosomes which act to protect the chromosome, shorten with age. Below a critical length, shorter telomeres are associated with cell senescence and prospective studies have found that telomere length predicts mortality.[100,101] In the first study to link social exposure to telomere length, Epel *et al.*[92] show that both objective indicators of stress and subjective reports of distress are associated with shorter telomere length. The association of stress and telomere length remained significant when adjusted for age, smoking, BMI, and vitamin use. A study of over 1500 adult female twins in the United Kingdom showed a link between social class and telomere length.[102] Women in manual occupational classes based on their own or their spouse's occupation had significantly shorter telomeres than those in nonmanual classes. Part of the difference was mediated through behavioral factors (e.g., smoking, exercise, and BMI), but significant differences remained when adjusted for these factors.

While much of the work on mechanisms has focused on adults, some researchers have identified mechanisms by which SES affects health during childhood and adolescence. These processes may set children on different health trajectories that will affect them over their lifespan. Starting even before birth, differences in the prenatal environment of babies born to mothers of different social classes can have lasting health implications. Children born to mothers with less education and income are more likely to be born prematurely and be smaller at birth.[51] Not only do such children have a higher neonatal mortality risk, but these conditions place them at greater risk of developing cardiovascular disease and other problems later in life.[103,104]

Beyond birth outcomes, experiences in early life that shape interpretations of social stimuli may serve as another mechanism by which SES affects health. Lower SES environments pose more threats and foster more interpersonal conflict. Repeated exposures

to such conflictual conditions may create expectancies that establish a lower threshold for perceiving threat. Expectations of threat may, in turn, increase the likelihood of negative affect and physiological stress responses. Chen *et al.*[105] found that high school students from low SES families did not differ from their high SES peers in interpreting clearly negative stimuli, but were more likely to interpret an ambiguous situation as threatening. The former had higher dystolic blood pressure, consistent with their displaying greater threat responses during ambiguous social situations. Low SES children and adolescents may develop a constantly vigilant stance that revolves around keeping the self safe, leading to a state of chronic stress.

The search for mechanistic pathways focuses on processes operating within individuals to illuminate psychobiological and behavioral processes by which SES can affect health. These mechanisms are, however, shaped by the environmental context in which they arise. Environments affect individuals through a variety of factors including social encounters that can impose stress responses as well as supportive encounters that can reduce them, social norms governing health behaviors, and enhanced or restricted resources for healthy living. In the next era of research, investigators paid more attention to these contextual factors of groups or environments to which an individual belongs, or inhabits.

Fourth era: multiple levels of influence

Along with continued research on specific mechanisms at the individual level including cognitive, affective, and behavioral responses to SES-related environments by which SES affects biology, work has evolved in a fourth era to examine mechanisms operating at multiple levels of influence. This work has focused on characteristics of the neighborhood and community as well as of the individual. This evolution was aided by the application of hierarchical and contextual models developed by statisticians that allow health disparities researchers to use neighborhood data in new ways. In earlier years, the socioeconomic characteristics of the neighborhood (e.g., mean income level, percent with college degree, percent unemployed) were sometimes used as a proxy for the characteristics of individuals residing in those neighborhoods.[106] However, neighborhoods may affect health through processes that operate at the neighborhood level, not simply because the community is composed of individuals with given socioeconomic resources. Interest developed in the contribution of the neighborhood apart from the characteristics of the individuals, not as a marker for them, and, the neighborhood itself became the focus of interest (see Diez Roux and Mair, in this volume). These studies have shown, for example, that individuals living in lower SES neighborhoods have poorer health related to the socioeconomic characteristics of the neighborhood, independent of their own SES.[107–109]

Studies in this era have examined the ecological embeddedness of risk factors for disease that differ by socioeconomic level (see "Clougherty, Souza, and Cullen, in this volume, for an analysis of the work environment). A number of these studies have identified environmental determinants of health behaviors, particularly those that contribute to overweight and obesity. Although described as a personal behavior, one's ability to eat a healthy diet and to exercise is affected by resources available to the person. The availability and relative cost of healthier foods such as fresh fruits and vegetables varies considerably across communities that vary by SES. Attention increasingly has focused on the built environment, with studies documenting more limited availability of resources in poorer communities[110–112] Low SES communities often lack supermarkets and residents are more dependent on convenience markets where produce is not only more expensive but less fresh and appealing. These same communities often lack recreational facilities and their residents may be inhibited from outdoor activities such as walking or jogging by fear of crime.[113]

The unjust distribution of environmental resources that enable healthy living and hazards that constrain healthy living contribute to the SES gradient of health behaviors, and hence health. The fourth era brought greater focus on the social attributes of residential areas and on the built environment. Increased understanding of how SES at the neighborhood level constrains healthy behaviors emerged in this era and gave rise to the concept of "behavioral justice."[114] This perspective argues that no group should bear a disproportionate share of health problems resulting from inadequate resources for engaging in healthy behaviors. Environments dominated by easy access to tobacco products and alcohol, fast food outlets, scarcity of

affordable and appealing fresh fruits and vegetables, and unsafe, uninviting community conditions that restrict physical activity, stack the odds against individuals in those communities achieving good health. The concept of behavioral justice provides a conceptual link between the individual (behavioral) level and the social (neighborhood) levels while multilevel analysis allows for empirical evaluation of their separate effects on health.

While the fourth era added analysis of multiple levels, the questions were generally framed in terms of independent effects (i.e., to what extent do neighborhood factors contribute to health independent of individual factors?). Analyses focused largely on main effects. Some studies, however, began to look at the effect of combinations of factors. In so doing they moved beyond main effects to analyze interactions in the context of multilevel analyses.

Fifth era: interactions, systems, and causality

Just as the introduction of the gradient in the second era added complexity and nuance to the categorical frame of the first, the third era's focus on mechanism added detail to flesh out the pathways from SES to health, and the fourth era added contextual information, research in the fifth era looks not only at independent associations of different domains but at how effects are moderated by combinations of factors.

A variety of interactions are being studied as illustrated by the examples given later.

The interaction of individual and neighborhood SES is a case in point. In addition to examining the effect of neighborhood income independent of one's own, studies are also asking whether the benefits of living in more affluent communities are similar for those with more and less income and/or education. Winkleby *et al.*[115] studied 82 neighborhoods in four California cities to examine whether the influence of individual-level SES on mortality differed by neighborhood-level SES. Neighborhood SES was defined by census variables including percent with less than a high school education, median annual family income, percentage blue-collar workers, percentage unemployed, and median housing value. Individual SES was defined by educational attainment and household income. Death rates for low SES women were highest in high SES neighborhoods, lower in moderate SES neighborhoods, and lowest in low SES neighborhoods. Men showed a similar pattern, although somewhat attenuated. These differences in mortality were not explained by individual baseline risk factors. These results suggest that low SES individuals may not benefit from the greater resources available in higher SES communities. The stress of having low relative standing in a high SES neighborhood, and potentially fewer resources to cope with stressful life events (e.g., social support and low perceived control), may play a role in the higher mortality of low SES individuals. Four other studies have examined the cross-level interaction between individual and neighborhood SES on mortality, three of which found similar results,[108,116,117] while one did not find a significant cross-level interaction.[118]

Racial/ethnic differences in health may also be moderated by neighborhood characteristics. Subramanian *et al.*[119] studied neighborhood variations in poverty and excess mortality. They found greater racial/ethnic disparities in some neighborhoods than in others, with the odds ratio for Blacks compared to Whites ranging from 0.31 to 5.36. The finding that neighborhood level poverty contributes to greater geographic heterogeneity in mortality rates for Blacks suggests that neighborhood deprivation may be particularly impactful for Blacks compared to Whites.

A different approach to understanding the intersection of SES and race/ethnicity is to examine how the effects of SES on health differ among racial/ethnic groups. For example, among Black and White men in CARDIA, a longitudinal study of the development of cardiovascular risk factors in adulthood, patterns of SES associations with cellular aging differ by race. Using stored blood, Epel *et al.* (personal communication) are examining socioeconomic differences in telomere length. As discussed earlier, telomeres cap the ends of chromosomes and shorten with age; shorter telomere length is predictive of cardiovascular disease and mortality. Preliminary results indicate that among White men, those with less education and lower household income have shorter telomeres and greater change in length over 5 years. However, SES is not related to telomere length among African-American men.

SES gradients in health outcomes among children also appear to differ by racial/ethnic group.

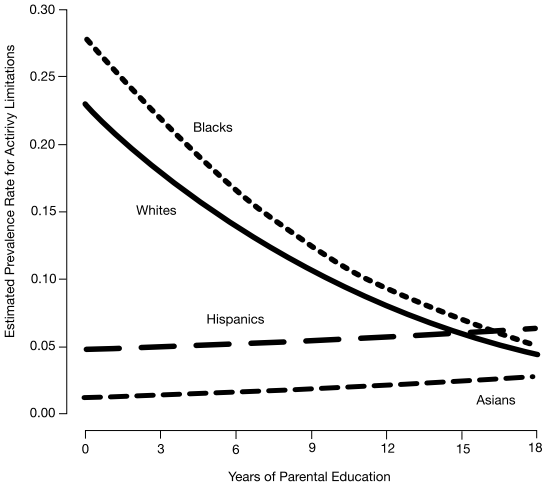

Figure 4. Parental education × race interaction for childhood activity limitation. *Note*: The education line was not significant among White and Black children but was significant for Hispanic and Asian children (*P*-values were <0.05). (Reprinted from Chen E., A. D. Martin & K. A. Matthews. 2006. Understanding health disparities: the role of race and socioeconomic status in children's health. *Am. J. Public Health* 96: 702–708, by permission from the *American Journal of Public Health*.)

Using data from the National Health Interview Survey, Chen *et al.*[120] found the usual SES gradients in health for White and Black children but not for Asian or Hispanic children (see Fig. 4). For example, the prevalence of activity limitations due to illness drops for Black and White children at higher levels of parental education. In contrast, there is little effect of parental education for Hispanic and Asian children who actually show a small increase in activity limitations as parental education increases.

These data underscore the importance of looking within each racial/ethnic group when examining the association of SES and health. Doing so is important not only because of possible interactions but because current measures of SES do not fully capture racial differences in socioeconomic position. For example, at the same income level African Americans have less wealth (assets like savings and home equity) than do Whites.[29] Wealth provides a reserve that protects against uncertainty in the labor market, helps reduce stress on families, and allows families to live in well-resourced communities. In terms of education, high school graduation may have a quite different meaning depending on the quality of the high school, something which often is quite discrepant among different racial/ethnic communities. New approaches are trying to assess these differences so that better comparisons can be made across groups.

In a different domain, researchers are increasingly considering the interaction of individual biology and social context. Boyce and his colleagues have found interactions between social context and temperament among children as well as in nonhuman primates.[121,122] In the Peers and Wellness Study (PAWS), children were followed through the kindergarten year to examine the effects of family SES and of the child's position in the peer group social hierarchy on school adjustment. Biological reactivity was assessed before the start of the school year in response to social, cognitive, and emotional challenges. Children from more adverse family environments (e.g., greater financial strain, marital conflict) exhibited more externalizing behaviors at the start of kindergarten, whether or not they showed greater biological reactivity. However, among children from low-adversity families, the extent of externalizing behaviors differed between children with high versus low reactivity, suggesting a greater impact of context on the more reactive children. On the other hand, school engagement showed a cross-over effect with low-reactivity children from high-adversity families slightly more engaged than their high-reactivity peers and high-reactivity children from low-adversity homes more engaged than their lower reactivity peers.

The evaluation of interaction effects is becoming more common in genetic research, with increasingly sophisticated work on the gene–environment interaction and on epigenetics. Miller *et al.*[83] show how a severe chronic stressor, caring for a family member with brain cancer, influences cortisol-mediated signaling in monocytes, the white blood cells that drive inflammation. Genes that cortisol usually switches on were not expressed as strongly in monocytes from caregivers as were those from non-caregiver controls, whereas genes that cortisol usually silences were more active in caregivers than in controls. This finding suggests a mechanism for how chronic stress may facilitate the pro-inflammatory gene expression cascade associated with coronary disease, autoimmune disorders, and infectious diseases. Findings by Caspi *et al.*[123] and Taylor *et al.*[124] show how genetic risk moderates the impact of

environmental exposures. Their work has shown that stress exposure increases the risk of depression primarily among individuals with a genetic polymorphism associated with vulnerability to depression (a short allele of the serotonin transporter gene). Those lacking the polymorphism did not experience a greater risk of depression with stress exposure.

Research on epigenetics is introducing further complexity into our understanding of the interaction of genes and environment. Studies are showing that environmental context can act upon the gene itself. Environmental conditions may influence gene expression and thus change resulting behavioral and/or biological outcomes. Animal studies conducted by Meaney[125] have shown that early experiences of maternal care or neglect affect offspring in multiple ways, including their stress-responsiveness and their later response to their own offspring. Insights from animal models are now being applied to humans and will provide opportunities to delineate more precise biological pathways by which social factors associated with SES affect health.

A few researchers are attempting to study the kinds of complex interactions linking SES and health using systems models that capture nonlinear, dynamic associations[126,127] These move beyond regression models and simple interactions to capture interdependent variables that change over time. In addition to modeling empirical relationships, computer simulations are extending the reach of this research to predict how policy or environmental changes might reverberate through a population and affect health. The greater sophistication of such analytic and conceptual models may facilitate more complex and complete understanding of disparities and of the potential value of different approaches to reducing them.

During this most recent era, researchers have also become more concerned about establishing causality.[128] The majority of studies linking SES and health are cross-sectional, reporting associations between a given SES indicator and a health outcome and attributing causality to the SES indicator. These designs cannot rule out alternative explanations, however, including potential endogeneity and reverse causation. These issues are especially important in evaluating the relationship of income and health since poor health entails financial costs and can also affect one's ability to work.[49] Yet even with education which is established earlier in life, causality may flow in both directions because childhood health problems may limit educational attainment[46,129] which in turn may affect health later in adulthood. Increasingly, studies are using longitudinal data and applying new statistical techniques to explore causal direction[130] along with novel experimental designs. Studies involving randomized interventions and natural experiments such as the Social Security "notch"[131] and economic change due to reunification in Germany[132] also allow more definitive tests of causality. While these studies have yielded mixed results, the preponderance of the evidence continues to support the impact of socioeconomic factors on health across the lifespan.

Conclusion

Each era of research has advanced our understanding of health disparities. In parallel to the unfolding eras of research designed to increase our understanding of the nature and causes of health disparities, there have been successive eras of thinking about intervention and policy. These, too, have shown increasing complexity and sophistication[133] (see Dow *et al.*, in this volume). Experimental programs such as PROGRESA (now known as Oportunidades) in Mexico are directly testing innovative policies. A number of such programs are providing evidence on whether incentive programs are effective, under what conditions, and for whom. These parallel advances foreshadow a sixth era of work on health disparities; one which translates evidence into policy and develops interventions and evaluation protocols based on the sophisticated understanding allowed by the aggregate of knowledge accrued across eras of health disparities research. New conceptual frameworks coupled with more sophisticated methodologies have allowed increasingly more detailed and nuanced examination of the realities of the social patterning of health. The chapters that follow explore where we stand today in the study of the determinants of health and the potential for eliminating the unjust disparities in the capacity of all people to achieve their maximal state of health.

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Conflicts of interest

The authors declare no conflicts of interest.

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