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SOCIOECONOMIC STATUS AND HEALTH: The Potential Role of Environmental Risk Exposure

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■ **Abstract** Among several viable explanations for the ubiquitous SES-health gradient is differential exposure to environmental risk. We document evidence of inverse relations between income and other indices of SES with environmental risk factors including hazardous wastes and other toxins, ambient and indoor air pollutants, water quality, ambient noise, residential crowding, housing quality, educational facilities, work environments, and neighborhood conditions. We then briefly overview evidence that such exposures are inimical to health and well-being. We conclude with a discussion of the research and policy implications of environmental justice, arguing that a particularly salient feature of poverty for health consequences is exposure to multiple environmental risk factors.

SOCIOECONOMIC STATUS AND HEALTH: THE POTENTIAL ROLE OF ENVIRONMENTAL RISK EXPOSURE

Satisfactory explanation for the ubiquitous socioeconomic status-health gradient remains elusive, suggesting, in part, that an adequate model of this relation is probably complex and multifaceted (1, 81). In this paper we provide an overview of data indicating that income is inversely correlated with exposure to suboptimal environmental conditions. By environmental conditions we mean the physical properties of the ambient and immediate surroundings of children, youth, and families, including pollutants, toxins, noise, and crowding as well as exposure to settings such as housing, schools, work environments, and neighborhoods. We also briefly cite evidence that each of these environmental factors, in turn, is linked to health.

The implicit conceptual model under discussion is as follows (Figure 1): As can be seen above, what we discuss is evidence for two necessary prerequisites for this model to be valid—namely that socioeconomic status (SES) is associated with environmental quality and, in turn, that environmental quality affects health. This is not equivalent, however, to the conclusion that SES effects on health are caused

SES ⇒ ENVIRONMENTAL ⇒ HEALTH QUALITY

Figure 1 Basic underlying conceptual model.

by differential exposure to environmental quality. There are few if any data directly testing this proposition. What is necessary to verify the model shown in Figure 1 is that the SES health link is mediated by environmental quality.

In addition to this fundamental shortcoming in the extant database, results on SES and environmental exposure tend to be restricted to income and, in several cases, are not continuous; instead they compare individuals below and above the poverty line. Furthermore, for certain salient environments, especially work and school settings, scant data are available on income-related differential exposures to hazardous, polluted, or inadequate building conditions. The reader should also bear in mind that for several of the income-related environmental exposure results, the data are confounded with ethnicity. Given that there is also evidence that nonwhite individuals, at least in the United States, are more likely to be exposed to health-threatening environmental conditions than are white individuals, it can be difficult to disentangle associations between income and environmental quality from racism.

There is also a conceptual issue we wish to briefly discuss before overviewing some of the evidence for linkages among SES, environmental quality, and health. Nearly all of the empirical work, and for that matter theoretical discussion about this issue, has examined individual environmental risk factors. Research and discussion tend to be focused on specific pollutants, toxins, or particular ambient conditions such as housing quality and each respective factor's link to income or health. We suspect that the potential of environmental exposure to account for the link between SES and health derives from multiple exposures to a plethora of suboptimal environmental conditions. That is, we would argue that a particularly important and salient aspect of reduced income is exposure to a confluence of multiple, suboptimal environmental conditions. The poor are most likely to be exposed not only to the worst air quality, the most noise, the lowest-quality housing and schools, etc., but of particular consequence, also to lower-quality environments on a wide array of multiple dimensions. We hypothesize that it is the accumulation of exposure to multiple, suboptimal physical conditions rather than any singular environmental exposure that will provide a fruitful explanation for the SES health gradient.

SOCIOECONOMIC STATUS AND ENVIRONMENTAL QUALITY

In this section we overview data on the relations between income or SES and exposure to environmental risks. We examine both individual environmental conditions such as toxic wastes, air pollution, crowding, and noise as well as the physical quality of specific settings such as the home, school, work, and neighborhood.

Hazardous Wastes

The environmental justice movement, launched in the 1980s, called attention to the fact that low-income citizens, and especially low-income, ethnic minority individuals, were much more likely to be exposed to toxic wastes and other forms of health-threatening environmental conditions relative to their more affluent and white fellow citizens (67). An influential book, *Dumping in Dixie* (18), documented the geographic association of toxic waste dumps in the Southeastern region of the United States with low-income, minority neighborhoods. The percentage of families below the federal poverty line in census tracts inclusive of EPA Region IV Hazardous Waste Landfills ranged from 26% (South Carolina) to 42% in Alabama. Twenty-nine percent of families living within one mile of a commercial hazardous waste facility in Detroit are below the poverty line, and 49% of them are nonwhite. More than 1.5 miles away, 10% are poor and 18% are people of color (89). One hundred percent of U.S. Government uranium mining and 4 of the largest 10 coal strip mines are located on Native American reservations (53). Nearly half of Native Americans live below the federal poverty line. More recent analyses of income and race differentials in hazardous waste exposure reveal similar trends (142). Children's body lead burden is strongly associated with both income and race. For example, in a recent EPA Task Force report, "Environmental Equity: Reducing Risk for All Communities" (136), 68% of urban black children in families with incomes below $6000 had blood lead levels that exceeded safe limits in comparison to 15% of the same population with incomes above $15,000. For white children, the comparable data were 36% and 12%. The National Health and Nutrition Survey conducted in 1980 and 1990 documents elevated blood-lead levels in low-income individuals, particularly among inner-city residents (105).

Air Pollution

Ambient pollutant exposure reveals similar race and income-related trends. Figure 2, for example, depicts factory carcinogen emissions in Britain in relation to income (42a). Analogous data have been found for several other, common ambient air pollutants (e.g., sulfur oxides, fine particulates) with known pathogenic effects in the United States (42). Exposure to ozone, a principal toxic component of photochemical smog, as well as fine particulate matter, in the South Coast Air Basin of California, is inversely related to income levels (15). The World Bank has also become interested in environmental justice, publishing sobering statistical summaries about environmental health threats worldwide. For example, in low-income countries from the 1970s to the late 1980s, the average levels of suspended particulate matter in cities increased from approximately 300 μg per cubic meter of air to 325 μg. The total range of measured particulates for all of these cities at both time periods exceeded even marginal, let alone acceptable, limits from a respiratory health standpoint. Cities in middle-income countries over the same time period witnessed improved air quality (from approximately 180 to 150 μg/cubic meter of air) and wealthy countries improved from $\sim$100 to 75 μg per cubic meter of air. Analogous data are provided by the World Bank for water quality (144).

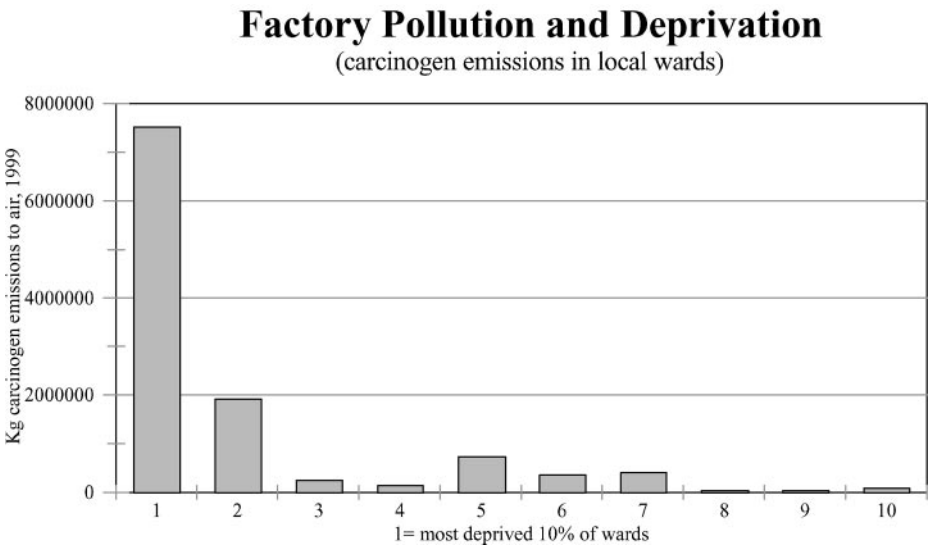

Figure 2 Factory pollution and income in England [reprinted by permission from Friends of the Earth, United Kingdom (42a)].

Today increasing interest is focused on exposure to indoor air quality, which may play an even greater role in the respiratory health and well-being of individuals, particularly young children. Levels of several common airborne toxins are higher indoors, and for young children, the duration of exposure is often greater inside relative to the outdoors. Although there are some suggestive data, with the exception of secondary cigarette smoke, little is known about the association between income levels and exposure to indoor air contaminants.

Parental smoking, which is inversely related to income levels, increases children's exposures to a wide variety of indoor toxins. For example, in the United States, 65% of preschool children living in poverty have been exposed to cigarette smoke at home in comparison to 47% of those not in poverty (94). In both the United States and Britain, mothers who are poorer are also less likely to quit and smoke more than their higher-income counterparts (54, 56). Length of tenure on welfare also predicts maternal smoking prevalence and consumption levels (55). Young children's levels of salivary cotinine increase linearly in relation to lower occupational class (27, 69). Cotinine is a metabolite of nicotine and a valid indicator of exposure to environmental tobacco smoke. Moreover, cumulative risk factors associated with poverty increase smoking prevalence in mothers of newborns. Rental occupied housing, lack of higher education, and single-parenthood status are associated with a ninefold increase in smoking among mothers of newborns in the United Kingdom (121). This association is independent of mother's age, parity, and ethnicity. Smoking during pregnancy is also highly correlated with maternal

TABLE 1 Radon exposure as a function of household income characteristics[a]

Percentage of households exceeding EPA safe limits (4 pCi/L) for radon		
Rental	**Owner occupied <$40,000**	**Owner occupied >$40,000**
66	41	36

[a]Adapted from Table 5, in Reference (22).

education. For example, 48% of American women who dropped out of high school smoke during pregnancy compared to 12% going beyond high school and 3% who are college graduates (95).

In rental units in the United States, 10% percent of households with incomes below the poverty line rely primarily upon hot air units without ducts, and 4% use unvented gas heaters as their primary heat source. For rental households with incomes exceeding $30,000, comparable figures are 7% and 1% for ductless hot air heat and unvented gas heaters, respectively (123). Toxic indoor air pollutants, NO_2 and CO, related to combustion processes (stoves, heating, smoking), are substantially higher in low-income, inner-city residences relative to U.S. averages (52, 116). Exposure to radon, a known carcinogen, is related to income levels in rural counties in New York state (see Table 1). Chi & Laquatra (22) suggest that income-related differences in radon exposure are probably related to structural deficiencies that provide more permeable vectors for radon to enter into the residence.

Acute respiratory obstructive diseases such as asthma are associated with serum IgE antibodies to dust mite feces, cats, cockroaches, and certain pollens. Exposure to cockroach allergens as well as antibody sensitivity is associated with socioeconomic status with 0%, 26%, and 46% of high-, middle-, and low-SES, respectively, children exposed (114). Positive skin tests data revealed a parallel SES gradient (114). Rosenstreich et al. (109) also found high levels of allergenic reactions to cockroaches in a general population sample of inner-city children and more than half of low-income asthma patients in several urban, inner-city samples evidenced specific IgE antibodies and positive skin test results to cockroaches (10, 72). Furthermore, dampness in houses, which is inversely associated with household income, is conducive to dust mites as well as molds and fungi, all related to respiratory obstructive disorders (51).

Water Pollution

Although most attention to environmental pollutants and income has been focused on hazardous wastes and air pollution, several case studies suggest higher levels of contaminated water among low-income populations (21). For example, 44% of water supplies for migrant farm workers in North Carolina tested positive for coliform and 26% for fecal coliform. For comparable farm areas in the same

region, both levels were at 0% (23). Low-income Chicano populations living along the U.S./Mexico border (Colonias) are plagued by contaminated drinking water. Estimates indicate, for example, that in Texas nearly 50% of the Colonias population lacks safe drinking water, a condition that is largely believed to be the source of the threefold increase in this population's risk for waterborne diseases relative to the overall morbidity rate in Texas (21, pp. 887–88). In 1984, EPA surveyed rural drinking water supplies in the United States and found significantly higher levels of coliform in low-income households (135). Finally, low-SES families are much more likely to swim in polluted beaches (20) as well as consume fish from contaminated waters (141). Statistics on access to safe, clean drinking water do not convey the full picture with respect to public health. For example, in many developing countries people designated as having access to suitable water supplies have to walk long distances to reach them, often averaging 30 minutes or more. Overburdened parents may not have the time or energy to utilize such distant facilities (6).

Ambient Noise

Exposure to ambient noise levels is also associated with income. According to data from the American Housing Survey, low-income residents are nearly twice as likely (9.1%) to report that neighborhood noise is bothersome in comparison to families not in poverty (5.9%) (118). A nationwide survey of major U.S. metropolitan areas found a strong, adverse correlation ($r = -0.61$) between household income and 24-h average sound level exposures (134). Households with incomes below $10,000 had average sound exposure levels more than 10 dBA higher than households above $20,000 annual income. Decibels is a logarithmic scale with an increase of 10 dBA perceived as approximately twice as loud. A recent analysis of airport noise and children's health and cognitive performance around Heathrow Airport documents linkages between income and actual, objective indices of noise exposure. As shown in Table 2, elementary schools with higher levels of aircraft noise exposure have greater percentages of children eligible for free lunches (58). Leq is an index of average intensity of sound exposure, measured in decibels.

Residential Crowding

Residential crowding, which is typically indexed by the ratio of people to number of rooms, is also linked to income. Figure 3 depicts national data from the 1990

TABLE 2 Aircraft noise exposure and elementary school poverty index[a]

	Low noise <57 Leq	**Moderate noise 57–63 Leq**	**High noise 64–72 Leq**
% Eligible for free lunch	14	23	28

[a]Adapted from Table 4 in Reference (58).

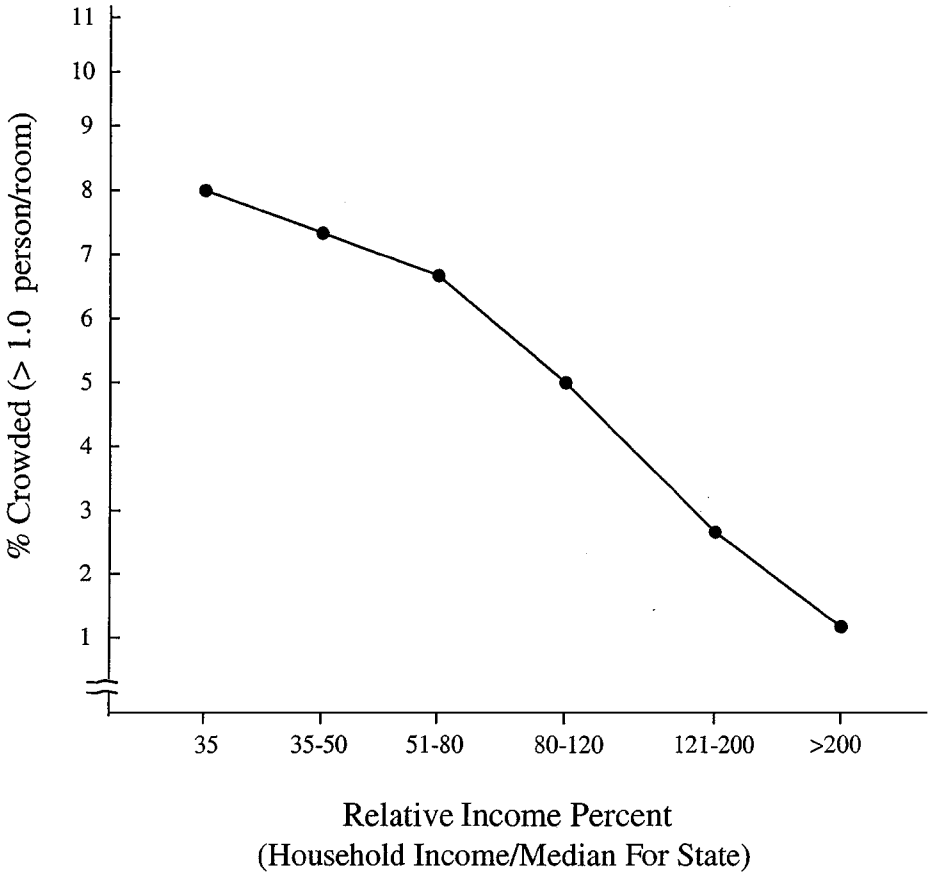

Figure 3 Residential crowding (greater than one person per room) and household income in the United States. Adapted from Table 1 in Reference (92).

census, showing a clear income-related gradient (92). The official U.S. Census definition of a crowded household is greater than one person per room.

Similar trends have been uncovered in economically underdeveloped countries. For example, in 1990 in Monterey, Mexico, 48% of households situated in the lowest income district of the city had one bedroom in comparison to 16% of households in the most affluent district (48). Similar trends have been uncovered in major urban areas in other developing countries (125).

The quantity and quality of space proximate to residences may also bear upon health and quality of life. Low-income neighborhoods in New York City have 17 square yards of park space per child, whereas all other New York City neighborhoods average 40 square yards of park space per child (118). In the United Kingdom, 86% of professionals and supervisors have access to a private garden at home in comparison to 69% of manual laborers (131). Manual laborers are four

times more likely (14%) to have a garden or yard at home too small to sit outside in the sun relative to professionals, managers, or supervisors.

Housing Quality

In addition to examining linkages between constituents of environmental quality and SES, one can also look at bundles of environmental quality as embodied in the overall quality of settings such as housing, schools, work, or neighborhoods. In the United States, housing quality is strongly tied to income levels, which in turn are positively associated with home ownership and negatively correlated with residential mobility (40). For example, approximately three quarters of those above the federal poverty line own their own home compared with 40% of those who are poor. Low-income families are five times more likely to be evicted than their non-poor counterparts. Statistics from the American Housing Survey, conducted by the U.S. Census, indicate that the poor are more than three times as likely to have substandard quality housing than the not poor (22% vs. 7%) (118). Thirty-six percent of all American households with a child under the age of 18 report at least one problem with housing compared to 77% of households at or below 50% of the median income for the surrounding geographic area (133). As is evident in Table 3, income is inversely related to various indicators of housing adequacy.

Analogous trends have been uncovered in a representative national sample of households in the United Kingdom (131). We have also found that housing quality is significantly correlated with the income to needs ratios ($r = -0.39$) of rural families in upstate New York. The income to needs ratio is a per capita poverty index formed by taking the ratio of family income to the federally defined poverty index. Thus an income to needs ratio of one equals the poverty line. The federal formula is adjusted annually to the cost of living index. We used a housing composite scale that relied on raters' assessments of cleanliness/clutter, indoor climate quality, privacy, exposure to safety hazards, and structural quality (38).

TABLE 3 Percentage of children living in houses with selected problems from the 1985–1989 American Housing Survey[a]

	Income decile		Income quintile	
	First	Second	Third	Fifth
Incomplete bathroom	2.5	2.2	.7	.6
No sewer/septic system	1.7	.9	.1	.0
No central heat	32.3	34.7	21.4	9.6
Holes in floor	7.0	5.8	1.4	.6
Open cracks (walls, ceiling)	19.9	15.9	6.3	3.2
Leaky roof	11.9	12.5	8.5	7.3
$\geq$1 person/room	19.2	23.4	10.9	5.3

[a]Adapted from Table 4.6 in Reference (87).

Social class differentials in childhood injuries from accidents in the home (e.g., falls) are correlated with hazardous characteristics of residential structures (11).

Poor families in America are also much less likely to have basic amenities such as clothes washers (72%), clothes dryers (50%), air conditioning (50%), or telephone (77%) than the not poor (clothes washer, 93%; clothes dryer, 87%; air conditioning, 72%; telephone, 97%) (40, 87). In the Netherlands, the percentage of persons with one or more housing deficiencies (no refrigerator, no washing machine, no clothes dryer, $\geq$1 person/room) is linearly related to income, ranging from 16% for families in the lowest income sextile to 1% of those in the highest income sextile (126).

Not surprisingly, the situation is even more extreme in the developing world. In Monterey, Mexico, income differences among districts in the city are associated with housing problems such as the absence of a permanent roof, no indoor running water, lack of drainage, and overcrowding (48). Looking at census tracts rather than metropolitan districts, Stephens and colleagues (125) uncovered similar trends in Accra, Ghana, and São Paulo, Brazil. In Accra, 37% of households in the lowest income census tracts have no piped in water, whereas 11% lack this amenity in wealthier areas of the city. In São Paulo, 36% of homes in the lowest income census tracts have no indoor toilets compared to 1% among more affluent tracts in the city.

Developmental psychologists have devised rating instruments to assess dimensions of the home environment of families. These instruments encompass measurements of physical qualities and evaluations of parenting and other aspects of the social environment. Figure 4 depicts a linear relation between the income-to-needs ratio and scores on a common residential environment rating scale, the HOME in the United States (47).

Bradley & Caldwell (13), the principal authors of the HOME scale, reported that the lower the SES, the poorer the HOME scores for infants and two-year-olds in the United States. More recently, Bradley and colleagues (14) examined relations between HOME scores across five biennial waves of a national sample of over 25,000 American children. Parental responsiveness (e.g., answering questions) was lower in poor versus not poor families, and these children had fewer learning resources (e.g., books, tape recorders) in their homes. Low-income homes were also more monotonous, dark, and contained more hazardous conditions. In another analysis using the HOME scale, 6- to 9-year-olds in American families below the poverty line suffered a 34% deficit in overall HOME scores relative to those in families with an income-to-needs ratio above four (88). Moreover, the longer the duration of childhood poverty, the stronger the negative association. Dubow & Ippolito (32) found a correlation of -0.54 between HOME scores and the number of years elementary school-aged children lived below the poverty line.

Sherman (118) provides a sobering statistic that may be indicative of the quality of the home environment available to children in the United States. Fifty-nine percent of children ages 3 to 5 who are poor have 10 or more books at home; 81% of children who are not poor have 10 or more books at home. Sadly, only 38% of low-income parents in the United States read on a daily basis to their preschoolers.

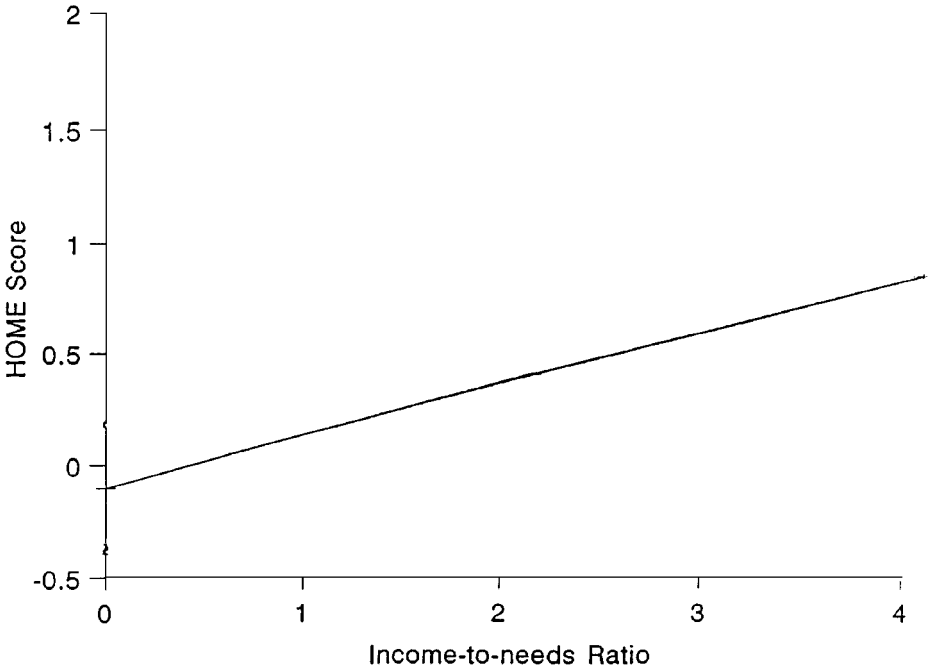

Figure 4 HOME scale values and income. Adapted from Figure 2, Reference (47), by permission from the University of Chicago.

Although substantially higher, the figure for their more affluent counterparts, 58%, is also dismal (133). Not surprisingly, the higher the socioeconomic status of the family, the more time youth spend reading on a daily basis (75). An interesting companion statistic that may interrelate to reading activity is television watching. Numerous studies have documented an inverse relation between household SES and youth TV viewing (75). For example, the percentage of 13-year-olds in the United States who watch more than five hours of television is 18 and 10, respectively, with household heads who did not graduate from high school or are college graduates (133).

In 1998, 94% of American urban children in predominantly low-income neighborhoods ($\geq$40% below poverty line) versus 57% of urban children living in neighborhoods with little poverty ($<$10% below poverty line) had no Internet access (73). Eighty-four percent of the former households and 35% of the latter had no access to a computer. Across the entire United States, 52% and 15% of elementary and secondary school children, respectively, who are in the bottom income quintile have computer access at home. This contrasts markedly with the 74% and 79% of elementary and secondary children, respectively, in the highest income quintile who have home computer access (133).

Educational Facilities

An important setting for children are schools and daycare environments. The quality of the school environment is tied to income. Per capita school expenditures vary greatly according to community resources given the reliance of many school districts on local property taxes. In 1999, a federal survey of physical facilities in a representative sample of 903 public elementary and secondary schools (93) found that 20% of schools had a building in less than adequate repair, 43% had at least one infrastructure deficiency (e.g., heating, indoor air quality), and about 10% were seriously overcrowded (greater than 125% capacity). Not surprisingly, as shown in Figure 5, predominantly low-income schools suffered a disproportionate burden of inadequate school facilities.

Table 4 provides summary data from the National Center for Education Statistics report on the Condition of America's Public School Facilities: 1999. As is apparent on every dimension, low-income schools fare worst. Moreover, on several indices of facility quality, there appear to be linear gradients in relation to income levels for the school.

Children in schools with a larger proportion of poor children are also more likely to be crowded. Twelve percent of American public schools with more than 70% of their children eligible for subsidized or free lunch programs are above 125% of building capacity in comparison to 6% of schools with less than 20% eligible for lunch programs (93).[1] In terms of health outcomes, low-income children are also more likely to live in seriously overcrowded households, defined as more than one person per room (see Figure 3 above). The adverse impacts of residential crowding are exacerbated among children in more crowded daycare facilities (86).

It is, of course, difficult to disentangle the quality of the physical plant from the social environment of schools. Perhaps the most fundamental resource in a school is the quality of its teachers. Secondary teachers in low-income schools are significantly less likely to have undergraduate majors or minors in the subjects they teach relative to those in more affluent schools. For example, 27% of secondary math teachers in poor school districts majored or minored in mathematics in college compared to 43% in school districts that are not predominantly low income (66). Comparable differences occur in the sciences, whereas the differential in English is smaller.

School safety is associated with income as well. Blue-collar adolescents are twice as likely to report the presence of weapons at school (12%) or fighting in school (32%) as their white-collar counterparts (44).

Recently, several authors have examined the quality of daycare in relation to income levels. The ratio of daycare staff to children as well as expenditure is related to income levels (96, 104). The educational level and pay scales of childcare workers are related to income as well (104). Both of these studies suggest that for

[1]The percentage of schools seriously overcrowded in the intermediate ranges of income, 20–39% school lunch eligible and 40–69% school lunch eligible, are 8% and 7%, respectively.

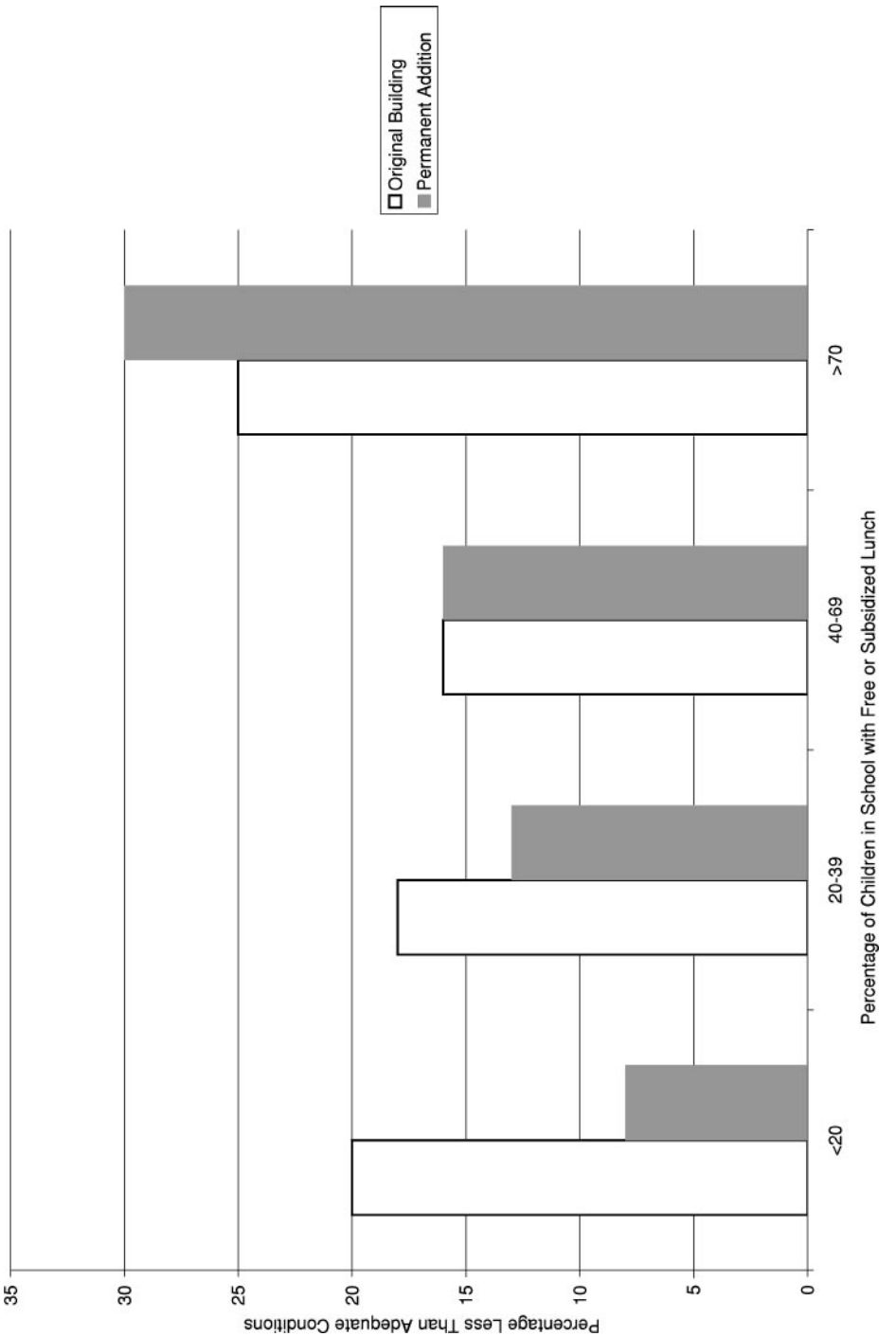
Original Building
Permanent Addition
Percentage Less Than Adequate Conditions
0
5
10
15
20
25
30
35
<20
20-39
40-69
>70
Percentage of Children in School with Free or Subsidized Lunch

TABLE 4 Percentage of building components inadequate in relation to percentage of children in the school eligible for free or subsidized lunch[a]

	Building Features								
Percentage eligible children	**Roof**	**Plumbing**	**Heating**	**Electric power**	**Lighting**	**Ventilation**	**Indoor air quality**	**Acoustics**	**Physical security**
<20	18	23	28	18	8	24	14	14	17
20–39	21	23	26	20	13	29	20	18	22
40–69	22	23	29	21	10	24	17	15	21
>70	32	32	35	30	19	29	24	25	17

[a]Adapted from Tables 4 and 8 of the National Center for Education Statistics (93).

the very poor, subsidies appear to offset daycare quality relative to the lower middle and working class for institutional daycare center care. For home care, the more typical income-quality gradient is seen, with poorer-quality home daycare associated with reduced family income. Phillips and colleagues have also documented that the quality of childcare provider-child interaction (e.g., sensitivity, harshness, detachment) is also correlated with income levels (104).

Work Environments

Outside of home and school, poorer people may be subject to greater health risks on the job. In a large sample of Swedish workers, Lundberg (80) assessed different environmental and behavioral factors believed to account for SES gradients in health. Of particular interest, the strongest predictor of the gradient was poor working conditions, defined as heavy lifting or tasks with repetitive strain plus daily contact with toxins, fumes, dust, explosives, vibration, and the like. Furthermore, in multiple regression models, poor working conditions were the only independent (i.e., entered last after all other factors) predictor of the SES health gradient. Emerging evidence documents pervasive race differentials in occupational exposure to toxins and physically hazardous, risky working conditions (43, 79, 145). For example, steelworkers located in the most hazardous component of the production process (topside of the coke ovens) are nearly three times more likely to be black than white. Among the most notoriously unhealthy labor sectors are seasonal agricultural work and sweatshop garment production—settings predominated by low-income workers. Moses et al. (91) review several studies suggesting a greater body burden of persistent chlorinated hydrocarbons among low-income, Chicano/Latino, and black agricultural workers. Although these substances are

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Figure 5 The percentage of inadequate original buildings and permanent additions in relation to the percentage of children in the school eligible for free or subsidized lunches. Adapted from Table 2, in Reference (93).

TABLE 5 DDE (DDT metabolite) serum ppb in relation to SES in Dade County, FL[a]

	Social class (Hollingshead 2 factor index)				
	I	**II**	**III**	**IV**	**V**
White	22.3	25.6	29.9	30.4	33.9
Black	33.1	37.2	29.1	43.8	50.5

[a]Adapted from Table 5 in Reference (30).

now banned in the United States, because they are lipophilic they remain sequestered in fatty tissue for many years. As indicated in Table 5, DDE serum levels are related to SES among blacks and whites in Dade County, Florida (30). DDE is a major metabolite of DDT and more indicative of lifelong exposure. Two aspects of these data are noteworthy. First, the data reveal a nearly perfect linear SES gradient, and second African Americans suffer much higher body-pesticide burdens. DDT concentrations in human breast milk among indigent black women in rural counties in Mississippi and Arkansas averaged 447 ppb. Average levels for middle-class women in Nashville averaged 14 ppb (143). In the National Health and Nutritional Examination Survey II, conducted from 1976–1980, living below the federal poverty line had a significant, independent association with serum DDT (odds ratio $= 1.48$) and dieldrin (odds ratio $= 1.43$) levels (124).

Given the robust association of ethnicity and income among American workers, it is reasonable to suspect that differential income-work setting quality relations exist as have been documented with respect to ethnicity. We know with some certainty that work-related injuries are inversely related to wages. Moreover, injury-caused sick days and duration of sick days per injury are both inversely associated with wages (60). Similar trends have been noted in the developing world (106). As shown in Table 6, occupational status in a large, representative sample of workers in the United Kingdom (131) is inversely related to more difficult working conditions.

TABLE 6 Percentage of U.K. men with difficult working conditions as a function of occupational status[a]

	Occupational status			
	Professional	**Managerial**	**Supervisory**	**Manual**
Working conditions				
Mainly outdoors	6	8	14	43
On feet all of the time	2	16	28	79
Work before 8 or at night	15	19	18	50

[a]Adapted from Table 12.2 in Reference (131).

TABLE 7 Age-adjusted mean number of hazard years (males)[a]

	British registrar general social class					
	I	**II**	**II Nonmanual**	**III Manual**	**IV**	**V**
Fumes/dust	4.02	12.34	5.36	30.19	19.92	19.10
Arduous labor	.86	11.33	5.45	19.52	20.80	12.58

[a]This table is based on previously unpublished data collected by L. Berney, D. Blane, G. Davey Smith, and P. Holland. This research was funded by the U.K. Economic and Social Research Council grant #L128251003.

Berney and colleagues (9) asked elderly individuals (M = 67.9 years) to retrospectively report the number of years during which they had been exposed to various environmental hazards, including those at work. Exposure to combined occupational hazards (i.e., fumes and dust, physically arduous tasks, lack of job autonomy) was inversely related to class. For example, male manual laborers had more than double the number of years working in hazardous conditions (M = 51.1 years) than nonmanual laborers (M = 20.9 years). Combined occupational hazards are expressed in years, cumulatively across hazards. Thus, for example, an individual exposed to 10 years of dust, 5 years in arduous labor, and 20 years in a job with low autonomy would be assigned a score of 35 hazardous years. Table 7 illustrates some additional analyses of these data, focusing on dust/fumes and arduous task demands as a function of occupational class.

Townsend (131), in his report of occupational class and working conditions in the United Kingdom, developed a composite index of working amenities that included sufficient heat in the winter for those outside, availability of tea/coffee, indoor toilet, facilities for washing/changing clothes, place to buy or eat lunch, secure place to keep coat/spare clothing, lockable personal storage, first-aid kit/facilities, possibility to make at least one call daily, and control over task lighting. He then constructed summary Working Conditions based on the number of amenities available: very poor working conditions, less than four amenities; poor working conditions, between four and six amenities; adequate working conditions, six amenities; and good working conditions, more than six amenities. Table 8 depicts data from this study on men in the United Kingdom working under different levels of overall work quality as a function of occupational status.

Investigation and concern about the plight of child laborers throughout the developing world has largely neglected the environmental conditions these children work in. In addition to long hours and dismal wages, many of these children work in deplorable conditions that are filthy, polluted, hazardous, and unsanitary (115).

Stressful, psychosocial conditions of working settings also appear related to occupational status. Marmot and colleagues (83) have shown among British civil

TABLE 8 Occupational status and percentage of men in the United Kingdom working at different levels of overall work setting quality[a]

	Occupational status			
	Professional	**Manager**	**Supervisory**	**Manual**
Overall work setting quality				
Very poor	0	4	4	13
Poor	2	8	5	17
Adequate	5	22	19	28
Good	93	66	72	42

[a]Adapted from Table A.41 in Reference (131).

servants that grade level is inversely related to autonomy (decision latitude) on the job, monotonous working conditions, and work pace. The trends are linear in relation to civil service grade (1 to 6) and, in turn, are related to sickness absence and incidence of coronary heart disease.

Neighborhood Quality

In addition to school, work, and home, local surroundings may contribute to health and well-being. Low-income urban neighborhoods suffer poorer basic municipal services [e.g., police, fire, sanitation (138)] and experience greater residential mobility (77) relative to more affluent, urban neighborhoods. Nine- to eleven-year-old children in Sydney, Australia, rated their overall neighborhood quality as higher in relation to an objective composite index of neighborhood risk, based upon census data (64). A primary component of this neighborhood risk index was SES. The higher the neighborhood risk index, the more likely it was that children rated their setting as having too much traffic, being dirty and polluted, too much noise, no safe places to play, and having fewer parks and outdoor play spaces. Even within predominantly low-income areas, family income is positively related to the overall quality of neighborhood housing and other amenities (120).

Macintyre and colleagues (82) found that working-class areas of Glasgow, Scotland, in comparison to upper-middle-class sections had fewer shops, paid more for food, had dramatically fewer recreational opportunities, were further from mass transit stops in combination with lower rates of car ownership, and had poorer street cleaning and maintenance. As noted earlier, low-income children have less access to parks and suitable nearby nature (e.g., gardens) (118). Furthermore, as shown by the Sydney study, children seem well aware of this (64). Playgrounds in low-income areas are more hazardous (as assessed by independent, trained raters) relative to those in higher-income neighborhoods (127). Moreover, young children of low-income families are much more likely to have no safe play areas nearby their home (131). Income-related rates of child pedestrian injuries appear to be caused by differential exposure to street traffic. For example, children in Montreal

from relatively disadvantaged schools cross 50% more streets a day, on average, than their more affluent schoolmates (82a). Basic housing stock is of significantly lower quality (percentage dilapidated housing) in low-income neighborhoods than in middle- or upper-income areas (71). Abandoned lots and boarded up houses also occur more frequently in low-income areas (128, 139).

Rates of exposure to crime are strongly tied to family income levels as well as neighborhood income composition (113). Children from low-SES neighborhoods are more likely to be exposed to aggressive peers than children from higher-income areas (119). Low-income adolescents perceive their neighborhood as more dangerous, violent, and of poorer overall quality (graffiti, cleanliness, housing quality) than their middle-class counterparts (2). Homel & Burns (64), in their Sydney neighborhood study, also found that neighborhood risk was linearly related to young children's judgments about the presence of unfriendly people. Thus, both the immediate residential environment as well as the neighborhood infrastructure of low-income individuals are likely to be of lower overall quality than the home or surroundings of people with more financial resources.

ENVIRONMENTAL QUALITY AND HEALTH

The section above documents pervasive income-related differences in exposure to environmental risks. The present section provides a much briefer summarization of evidence that the disproportionate burden of suboptimal environmental exposure shared by those who are poorer could have health consequences. The amount and quality of research on environmental effects on health and well-being are substantially greater than evidence of income differentials in exposure to poor environmental quality.

Air Quality

A voluminous literature relying on epidemiological studies as well as human and animal experiments demonstrates that ambient air pollutants cause various respiratory problems including bronchitis, emphysema, and asthma. Less well-documented links exist between certain ambient pollutants and lung cancer. Exposure to carbon monoxide may also be a risk factor for coronary heart disease. In addition, ambient air pollution may increase risk for respiratory infection (63, 78, 98). Exposure to ambient pollutants, principally ozone, a toxic component of photochemical smog, has been linked to psychological distress, negative emotional affect, and behaviors including interpersonal attraction and aggression. The latter function appears to be curvilinear, with moderate levels of irritable pollutants causing increased aggression (33, 110). Although a relatively new area of inquiry, there is already an impressive body of literature linking indoor air quality, including environmental tobacco smoke, with various respiratory problems (5, 68, 112).

Environmental Toxins

Environmental toxins, principally heavy metals (e.g., lead), solvents (e.g., cleaning fluids), and pesticides, occur in hazardous waste-disposal facilities and various manufacturing, mining, and agricultural activities. Toxicological effects include cancer, respiratory morbidity, brain damage, and various neurotoxicological difficulties (70, 98, 117). In utero exposure to several toxins also produces teratological effects. Many of these same toxins in much lower doses produce cognitive and behavioral abnormalities, including attentional and memory disorders, lower IQ, and poorer academic achievement. Behavioral problems including impulse control, frustration intolerance, and aggression have also been associated with several toxins (3, 108). The low-dose behavioral toxicological effects appear to be especially dangerous during the critical period of fetal development.

Ambient Noise

Another aspect of environmental quality, ambient noise levels, also appears to threaten health. Links between chronic noise exposure and hearing damage are well documented (74). Both intensity and duration of exposure are important parameters of noise exposure and health. Suggestive data link noise exposure to coronary heart disease and hypertension, but the evidence is not solid (8, 130). Several community studies have shown that children's blood pressure and possibly neuroendocrine stress hormones are elevated when living or attending schools in the flight paths of major airports (34). There are contradictory findings on ambient noise exposure and prematurity and birth defects, as well as a small number of studies suggesting immunosuppression from noise in animal models (34).

Noise clearly interferes with complex task performance (e.g., dual tasks) but has inconsistent effects on simple tasks (e.g., vigilance) (35). Several studies have uncovered evidence that both acute as well as chronic noise exposure can lead to motivational deficits linked to learned helplessness (25, 34). Glass & Singer (50) found, for example, that immediately following exposure to 20 minutes of noxious noise in the laboratory, subjects were less likely to persist at challenging puzzles. Their data also indicate that it is the uncontrollability of noise, in particular, that is problematic for motivation. A large number of studies have shown that chronic noise exposure is linked to reading deficits in young children. The effects on reading are not due to hearing loss. Moreover, some of this effect is due to problems with speech perception in noise-exposed children (36). Noise also has adverse consequences for interpersonal processes including altruism and aggression (26). Conclusions about an association between ambient noise exposure and mental illness are not well substantiated (122).

Residential Crowding

Crowding, like noise, functions as a stressor, elevating blood pressure and neuroendocrine parameters (34). Several studies have indicated that infectious diseases

are more likely in relation to crowding among vulnerable subgroups (e.g., prisoners, refugee camps) and that residential crowding (i.e., people per room) is associated with psychological distress in the general population (34). There is no evidence to substantiate the widespread perception of cultural differences in tolerance for crowding (37). Areal indices of density (e.g., people/acre) appear less important than interior density measures such as people per room for understanding health outcomes associated with crowding. Several studies indicate that a principal pathway linking residential crowding to psychological distress is problems with unwanted social interaction (7, 34). Residents of more crowded homes are more socially withdrawn and perceive lower levels of social support in comparison to individuals living in less crowded settings. Parents in crowded homes are also less responsive to their children and tend to employ harsher, more punitive parenting styles (34). Crowding may also interfere with complex task performance and has been linked to learned helplessness (34, 35). Relations between crowding and aggression are unclear but several studies have indicated reduced altruism and more negative interpersonal interactions in more crowded settings (7).

Housing Quality

Concerns about housing quality and physical health are a longstanding interest within the field of public health. Because of the design of research projects investigating housing and health, it is difficult to draw definitive conclusions; nonetheless, the preponderance of evidence suggests that substandard and more hazardous construction is associated with more unintentional injuries, especially among young children and the elderly. Inadequate heating systems and the presence of dampness, molds, and other allergens are also associated with poor respiratory health (19, 65, 85). Epidemic increases in asthma in inner-city settings may be partially attributable to elevated ambient pollutants along with exposure to allergens in the home. The evidence linking housing and health includes several longitudinal analyses of housing improvements and at least one study with random assignment.

Work investigating a possible link between housing quality and mental health is more controversial. The findings are less numerous and consistent than the physical health research. Evidence suggests that high-rise housing may be linked to elevated psychological distress among low-income women with young children as well as with restricted, outdoor play activities in young children (39, 49, 59).

There is also a good deal of evidence showing relations between the design of public housing and both fear of crime and actual incidence of crime (128). One of the problems with research on mental health and housing is reliance on housing measurements developed originally to assess physical health. Recent work indicates that scales indexing behaviorally relevant aspects of housing may prove more fruitful in research on housing and psychological well-being (38).

The quality of the home environment has also been linked to children's cognitive development. The provision of adequate learning materials and the absence

of chaotic conditions predict better achievement, both cross sectionally and longitudinally (12, 84, 137). The role of structure and predictability in family routines has also been implicated in children's socioemotional development (41).

Educational Facilities

The quality of the research on the physical environment of daycare settings and early school environments and children's development is not sufficiently developed to draw definitive conclusions, but trends indicate that the physical environment may play a role directly affecting children's cognitive and social development and indirectly by way of changes in teachers' behaviors (90, 132). Some of the physical characteristics of schools, in addition to noise and crowding, believed to be important to cognitive development include structure and predictability, arrangement and quality of activity areas, degree of openness, privacy, access to nature, availability and variety of age-appropriate toys and learning aids, and play materials for fine and gross motor development that provide graduated challenge, and natural light (101, 140).

Neighborhood Quality

There has been a recent upsurge of interest in neighborhood effects on well-being, focusing on cardiovascular health, crime and violence, and children's development. Some studies look at neighborhood effects, after statistically controlling for individual variation in SES or income levels. Other studies employ hierarchical linear modeling techniques that account for both individual and areal-level variation in SES or income. Low-SES neighborhood characteristics, independent of household SES, are associated with higher all-cause mortality (29, 57); greater cardiovascular risk in men (29, 61), as well as women (29); cardiovascular disease in men and women (29, 76); and with injury mortality (28). As noted earlier, exposure to urban crime is positively associated with both individual income levels and neighborhood income characteristics (113). Interestingly from a psychological health perspective, a key underlying mechanism to explain the linkage between neighborhood poverty and crime is diminished collective efficacy. Residents of low-income, high-crime neighborhoods perceive less social cohesion and diminished social control in their neighborhoods relative to persons living in lower-crime areas (113). Fear of crime in adults, particularly the elderly population, has reached epidemic proportions in low-income, inner-city neighborhoods (103, 139). Finally, exposure to violence has well-documented, adverse consequences on children's socioemotional development (45, 46, 102, 107).

Children growing up in high-SES neighborhoods have a clear advantage in school readiness and perform better academically, independently of familial income or education (77). Mental health in children and youth, particularly externalizing behaviors (acting out, aggression), is associated with residence in low-income neighborhoods. Studies controlling for individual SES as well as multiple level analyses converge on these findings. Adolescents in low-income neighborhoods

also appear to become sexually active earlier and are more likely to become teenage parents compared to their peers living in more affluent neighborhoods (77).

CONCLUSIONS

We have reviewed data showing that income is associated with exposure to a wide variety of environmental quality indicators in the ambient environment, at home, in school, on the job, and in one's neighborhood. Differential income and racial exposure to environmental health risks constitute an important and emerging field of scholarship and public policy, frequently termed environmental justice. It would be fair to summarize this body of work as showing that the poor and especially the non-white poor bear a disproportionate burden of exposure to suboptimal, unhealthy environmental conditions in the United States. Moreover, the more researchers scrutinize environmental exposure and health data for racial and income inequalities, the stronger the evidence becomes that grave and widespread environmental injustices have occurred throughout the United States. Such findings moved former President Clinton to establish an Office of Environmental Justice in 1992 within EPA (99, 136) and in 1994, to issue an executive order requiring all federal agencies to identify and address disproportionately high and adverse human health or environmental effects of federal programs and policies on minority and low-income populations (24). [See also the Office on Minority Health (100) within the Department of Health and Human Services and the National Institute for Environmental Health Sciences (97) for further information on U.S. Federal environmental justice programs. Friends of the Earth, United Kingdom, has a research and policy program devoted to environmental justice (42b).]

There are several gaping holes in the current database necessary to critically examine whether the SES health gradient could be partly attributed to environmental exposures. First, data on income or SES and environmental exposure are quite thin for several important settings, especially work, schools, and neighborhood settings. In several instances, a dose-response function is not available; rather, measures of environmental risk for low-income individuals are compared to persons above the poverty line. It would be preferable to have data across the continuum of income or SES and environmental risk exposure. In many instances, the poverty/not poverty comparison is entangled with ethnicity. In the cases of exposure to hazardous waste sites and to occupational risk exposure, respectively, the data on ethnic differentials in exposure are better developed than they are for income. Available data are largely confined to North America and Western Europe. The paucity of data on income and environmental risk for residents of developing countries is particularly troublesome given both the greater population size and more adverse environmental risk exposure in many of these countries.

Second, we hypothesize that the likelihood of singular environmental exposure accounting for the SES health gradient is small. We believe that it is the confluence of suboptimal conditions that is most likely to function as a potent mechanism

helping to account for SES-related differences in health. Research on cumulative risk exposure among children offers a useful analogue. This work shows that children exposed to one or perhaps two serious risk factors suffer at most modest decrements in psychological or cognitive functioning. However, the accumulation of multiple risk factors dramatically elevates the probability of adverse socioemotional and cognitive developmental outcomes (16, 111). The gap in our analysis of income, environmental risk, and health is such that few data exist showing the relation between income and multiple sources of environmental risk. We do know with some clarity that income is inversely related to exposure to a higher frequency of social stressors and to more adverse social stressors (4, 17) but parallel data for multiple physical stressor exposure do not exist.

Should this multiple exposure, health, and income hypothesis prove correct, then current estimates of the importance of environmental risk to account for some of the SES health gradient are likely conservative. Nearly all of the available data on environmental risk and income emanate from economically developed countries; whereas the greatest convergence of multiple suboptimal environmental conditions with the severest health consequences likely occurs in the less developed world (62, 115).

The third serious deficiency in the current database for claiming that adverse environmental exposure might account for the SES health gradient is the absence of any data testing for the mediational model depicted in Figure 1. To our knowledge, no data indicate that the effects of poverty or income on health are mediated by exposure to multiple environmental risk factors. Therefore what we have shown herein can be summarized as follows:

- Income is often directly related to environmental quality, especially when low-income samples are contrasted with samples that are not poor;
- Environmental quality is inversely related to multiple physical and psychological health outcomes.

Greater progress in addressing the model shown in Figure 1 will require the collection of environmental risk and health data broken down by income or SES levels. Currently, such databases remain the exception. The absence of longitudinal studies also raises the possibility that the relations among income, environmental risk, and health are due to selection factors rather than environmental effects. Such a person-based explanation seems unlikely to account for the wide array of differential, environmental exposure shown herein, but changes in environmental conditions intra-person would provide stronger evidence of an environmentally based mechanism for the SES health gradient than the current preponderance of cross-sectional data. Reliance on cross-sectional data also precludes examination of the temporal course of environmental risk exposure and health in relation to income. Use of hierarchical linear modeling would also enable investigators to tease out nested, ecological niches of environmental exposure (e.g., region, neighborhood, home, work, school) in relation to income, class, or ethnicity (31).

In summary, public health databases need to routinely incorporate information about income and ethnicity. Such databases ideally would be longitudinal, sample

across a continuum of income levels, and incorporate whenever possible multiple ecological niches of environmental exposure. Given the income and multiple environmental risk hypothesis, it would also behoove us to construct exposure estimates that include multiple environmental risk factors. This would enable scientists and policy makers to examine whether low-income persons and other disadvantaged individuals are exposed to higher levels of combined environmental risks and, in turn, determine if such multiple risk exposure helps account for their higher levels of morbidity and mortality. Public health professionals should be alert to the reasonable possibility that scrutiny of isolated, distinct physical and/or social risk factors misrepresents the ecology of environmental risk. This misrepresentation might, in turn, lead to underestimation of the contribution of environmental risk exposure to the public's health.

There is clearly consistent evidence that people who are poorer in the United States are more likely to be exposed to multiple, environmental risks that portend adverse health consequences. Exposure to multiple, suboptimal environmental risk factors is one viable mechanism among several that could be a partial explanation for the gradient between SES and multiple health outcomes.

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