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THE RELEVANCE OF MALTHUS FOR THE STUDY OF MORTALITY TODAY: LONG-RUN INFLUENCES ON HEALTH, MORTALITY, LABOR FORCE PARTICIPATION, AND POPULATION GROWTH

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ABSTRACT

This paper argues that the secular decline in mortality, which began during the eighteenth century, is still in progress and will probably continue for another century or more. The evolutionary perspective presented in this paper focuses not only on the environment, which from the standpoint of human health and prosperity has become much more favorable than it was in Malthus's time, but also on changes in human physiology over the past three centuries which affect both economic and biomedical processes. A great deal of emphasis is placed on the interconnectedness of events and process over the life cycle and, by implication, between generations.

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The Relevance of Malthus for the Study of Mortality Today: Long-Run Influences on Health, Mortality, Labor Force Participation, and Population Growth

Research during the past two decades has produced significant advances in the description and explanation of the secular decline in mortality. My assigned task in this paper is to reconsider Malthus's theory of mortality on the basis of these findings and to assess what aspects of his theory might remain relevant to policymakers in both rich and poor countries.

In the course of this paper I will argue that the secular decline in mortality, which began during the eighteenth century, is still in progress and will probably continue for another century or more. The evolutionary perspective presented in this paper focuses not only on the environment, which from the standpoint of human health and prosperity has become much more favorable than it was in Malthus's time, but also on changes in human physiology over the past three centuries which affect both economic and biomedical processes. A great deal of emphasis is placed on the interconnectedness of events and processes over the life cycle and, by implication, between generations.

Such a perspective conflicts with much of Malthus's theory of mortality. In his view "normal" life expectation was fixed, and society was evolving toward a stationary state. Variations in mortality were related to the pressure of population on the land and on the existing stock of capital. Although Malthus allowed for the possibility that the arts might change in a salutary direction, the room for such improvements received scant attention in all the various editions of An Essay on the Principle of Population (1798). There is not the slightest inkling that Malthus foresaw a Britain with four times the population of his day and fifty times its income. As far as longevity is concerned, Malthus's best hope was that through prudent restraint the poor might approach the health and life expectations of the rich, which at the close of the eighteenth century was less than 50 years at birth. He certainly did not foresee that even the imprudent poor, living in a world of vice that rivaled anything he preached against, would in the 1990s have life expectations half again as large as that which he considered the upper limit of life.

Despite all the different ways in which Malthus misread the future, the central proposition of An Essay, that much misery was caused by the pressure of population against available resources, remains valid today, particularly for the poor countries of the world. Although the world is much richer than it was two centuries ago, it is still not rich enough to provide all of the poor nations of the world with the standard of life that has become conventional in the OECD nations. And the degradation of the environment that is associated with the unprecedented increase in population since World War II threatens, not only to impede progress in the Third World, but to impede, if not reverse, the progress of the OECD world.

The balance of this paper is divided into three parts. Part I deals with recent findings about the relationship of nutrition and physiology to the secular decline in mortality in Europe and America, and the bearing of these findings on Malthus's theory of mortality. Part II reconsiders the implications of Malthusian theory for economic and health policies in the Third World in light of recent findings on secular trends in health and certain aspects of human physiology in Europe and America. Part III is concerned with a set of issues that are outside of the Malthusian intellectual framework and that are likely to become predominant over the next several decades. Central to the new work are the debates on the upper limit to life, on the capacity to roll back the onset of chronic diseases through alterations in lifestyle and medical interventions, on the possibilities for extending economic productivity past age 65, and on the implications of these issues for meeting pension obligations during the next 3 to 7 decades.

I. Some New Findings on the Secular Decline in Mortality

During the middle of the eighteenth century mortality rates began to decline in England and France.[1] These declines continued for about three-quarters of a century and then leveled off for about a half century. The declines resumed during the last quarter of the nineteenth century and have continued to the present. Similar movements in death rates have been reported for the Scandinavian countries and for North America. However, it was not until the second decade of the twentieth century that demographers and epidemiologists became aware that the West was in the midst of a major secular reduction in mortality, and at first only the most recent wave of the decline was apparent. A concerted drive to explain the trend began in the 1920s, one aspect of which was an effort to develop a series that would show not only how far back in time the decline extended but would also show its spatial dimensions. Work on documenting the earlier phase of the decline began near the beginning of World War I and continues to the present.

Between the late 1930s and the end of the 1960s a consensus emerged on the explanation for the secular trend. A United Nations study published in 1953 attributed the trend in mortality to four categories of advances: (1) public health reforms; (2) advances in medical knowledge and practices; (3) improved personal hygiene; and (4) rising income and standards of living. A United Nations study published in 1973 added "natural factors," such as the decline in the virulence of pathogens, as an additional explanatory category.

A new phase in the effort to explain the secular decline in mortality was ushered in by Thomas McKeown who, in a series of papers and books published between 1955 and the mid 1980s, challenged the importance of most of the factors that previously had been advanced for the mortality decline. He was particularly skeptical of those aspects of the consensus explanation that focused primarily on changes in medical technology and public health reforms. In their place he substituted improved nutrition, but he neglected the synergism between infection and nutrition and so failed to distinguish between diet and nutrients available for cellular growth. McKeown did not make his case for nutrition directly but largely through a residual argument after having rejected other principal explanations. The debate over the McKeown thesis continued through the beginning of the 1980s. However, during the 1970s and 1980s it was overtaken by the growing debate over the elimination of mortality crises as the principal reason for the first wave of the mortality decline.

The systematic study of mortality crises and their possible link to famines was initiated by Meuvret in 1946. Such work was carried forward in France and numerous other countries on the basis of local studies that made extensive use of parish records. This line of research was greatly accelerated by Goubert's 1960 study of Beauvais (cf. Goubert 1965). By the early 1970s, several scores of such studies had been published covering the period from the seventeenth through the early nineteenth centuries in England, France, Germany, Switzerland, Spain, Italy, and the Scandinavian countries (Smith 1977; Flinn 1981). The accumulation of local studies provided the foundation for the view that mortality crises accounted for a large part of total mortality during the early modern era, and that the decline in mortality rates between the mid-eighteenth and mid-nineteenth centuries was explained largely by the elimination of these crises, a view that won widespread if not universal support.

It was only after the publication of death rates based on large representative samples of parishes for England and France that it became possible to assess the national impact of crisis mortality on total national mortality.[2] Analyses of these series confirmed one of the important conclusions derived from the local studies:

Mortality was far more variable before 1750 than afterward. They also revealed that the elimination of crisis mortality, whether related to famines or not, accounted for only a small fraction of the secular decline in mortality rates. About 90 percent of the drop was due to the reduction of "normal" mortality (Wrigley and Schofield 1981; Dupâquier 1989; Weir 1989; Fogel 1993b).

In discussing the factors that had kept past mortality rates high, the authors of the 1973 United Nations study of population noted that "although chronic food shortage has probably been more deadly to man, the effects of famines, being more spectacular, have received greater attention in the literature" (142). Similar points were made by Lebrun (1971) and Flinn (1974, 1981), but it was not until the publication of the INED data for France (Blayo 1975) and the Wrigley and Schofield (1981) data for England, that the limited influence of famines on mortality became apparent (cf. Dupâquier 1989). In chapter 9 of the Wrigley and Schofield volume, Lee (1981) demonstrated that although there was a statistically significant lagged relationship between large proportionate deviations in grain prices and similar deviations in mortality, the net effect on mortality after five years was negligible. Similar results were obtained by studies of France (Weir 1982, 1989; Richards 1984; Galloway 1986) and Sweden (Bengtsson and Ohlsson 1984, 1985; Galloway 1987; cf. Eckstein, Schultz, and Wolpin 1984).

By demonstrating that famines and famine mortality are a secondary issue in the escape from the high aggregate mortality of the early modern era, these studies have indirectly pushed to the top of research agendas the issue of chronic malnutrition and its relationship to the secular decline in mortality. It is clear that the new questions cannot be addressed by relating annual deviations of mortality (around trend) to annual deviations of supplies of food (from their trend). What is now at issue is how the trend in chronic malnutrition might be related to the trend in mortality and how to identify the factors that determined each of these secular trends.

The current concern with the role of chronic malnutrition in the secular decline of mortality does not represent a return to the belief that the entire secular trend in mortality can be attributed to a single overwhelming factor. Specialists currently working on the problem agree that a range of factors are involved, although they have different views on the relative importance of each of the factors. The unresolved issue, therefore, is how much each of the various factors contributed to the decline. Resolution of the issue is essentially an accounting exercise of a particularly complicated nature that involves measuring not only the direct effect of particular factors but also their indirect effects and their interactions with other factors. An important aspect of the current work on chronic malnutrition is its consistency not only with the synergy between nutrition and infection (Scrimshaw, Taylor and Gordon 1968: Preston and van de Walle 1978), but also with the search for pathways through which the balance between pathogens and human hosts may have changed, a point that has been emphasized by Fridlizius (1984), Perrenound (1984, 1991), Alter and Riley (1989), Schofield and Reher (1991), among others (cf. Fogel 1994).

An unfortunate aspect of some past studies of the contribution of improvements in nutritional status to the secular decline in mortality has been the implicit assumption that *diet* alone determines *nutritional status*. However, epidemiologists and nutritionists are careful to distinguish between these terms. To them *nutritional status* denotes the balance between the intake of nutrients and the claims against it. It follows that an adequate level of nutrition is not determined solely by *diet*, which is the level of nutrient intake, but varies with individual circumstances. Whether the diet of a particular individual is nutritionally adequate depends on such matters as his level of physical activity, the climate of the region in which he lives, and the extent of his exposure to various diseases. As Nevin S. Scrimshaw put it, the adequacy of a given level of iron consumption depends critically on whether an individual has hookworm.[3]

Thus, a population's nutritional status may decline at the same time that its consumption of nutrients is rising if the extent of its exposure to infection or the degree of its physical activity is rising even more rapidly. It follows that the assessment of the contribution of nutrition to the decline in mortality requires measures not only of food consumption but also of the balance between food consumption and the claims on that consumption. To avoid confusion I will use the terms *diet* and *gross nutrition* to designate nutrient intake only. All other references to nutrition, such as *nutritional status*, *net nutrition*, *nutrition*, *malnutrition*, and *undernutrition* will designate the balance between nutrient intake and the claims on that intake.

1.1 Energy Cost Accounting and Size Distributions of Calories

In developed countries today, and even more so in the less developed nations of both the past and the present, the basal metabolic rate (BMR) is the principal component of the total energy requirement. The BMR--which varies with age, sex, and body weight--is the amount of energy required to maintain the body while at rest; it is the amount of energy required to maintain body temperature and to sustain the functioning of the heart, liver, brain, and other organs. For adult males aged 20-39 living today in moderate climates, BMR normally ranges between 1,350 and 2,000 kcal per day, depending on height and weight (FAO/WHO/UNU 1985, 71-72; Davidson et al. 1979, 19-25; Quenouille et al. 1951) and for reasonably well-fed persons normally represents somewhere in the range of 45 to 65 percent of total calorie requirements (FAO/WHO/UNU 1985, 71-77). Because the BMR does not allow for the energy required to eat and digest food, nor for essential hygiene, an individual cannot survive on the calories needed for basal metabolism. The energy required for these additional essential activities over a period of 24 hours is estimated at 0.27 of BMR or 0.4 of BMR during waking hours. In other words, a survival diet is 1.27 BMR.[4] Such a diet, it should be emphasized, contains no allowance for the energy required to earn a living, prepare food, or any movements beyond those connected with eating and essential hygiene. It is not sufficient to maintain long-term health but represents the short-term maintenance level "of totally inactive dependent people" (FAO/WHO/UNU 1985, 73).

Energy requirements beyond maintenance depend primarily on how individuals spend their time besides sleeping, eating, and essential hygiene. This residual time will normally be divided between work and such discretionary activities as walking, community activities, games, optional household tasks, and athletics or other forms of exercise. The energy requirements of a large number of specific activities (expressed as a multiple of the BMR requirement per minute of an activity) have been worked out (see table 1 for some examples). In order to standardize for the age and sex distribution of a population, it is convenient to convert the per capita consumption of calories into consumption per equivalent adult male aged 20-39 (which is referred to as a *consuming unit*). Energy cost accounting is usually worked forward, going from a list of activities to an estimate of the average daily caloric requirement, but such accounting can also be worked backward, going from the average caloric intake to the residual (after deducting the survival level of energy) available for work and discretionary activities.

Size distributions of caloric consumption are one of the most potent instruments used in assessing the plausibility of proffered estimates of average diets. They not only bear on the implications of a given level of caloric consumption for morbidity and mortality rates, but they also indicate whether the calories available for work are consistent with the level of agricultural output and with the distribution of the labor force between

Table 1

Examples of the Energy Requirements of Common Activities Expressed as a Multiple of the Basal Metabolic Rate (BMR) for Males and Females

Activity	Males	Females
Sleeping	1.0	1.0 (ie. BMR x 1.0)
Standing quietly	1.4	1.5
Strolling	2.5	2.4
Walking at normal pace	3.2	3.4
Walking with 10-kg load	3.5	4.0
Walking uphill at normal pace	5.7	4.6
Sitting and sewing	1.5	1.4
Sitting and sharpening machete	2.2	--
Cooking	1.8	1.8
Tailoring	2.5	--
Carpentry	3.5	--
Common labor in building trade	5.2	--
Milking cows by hand	2.9	--
Hoeing	--	5.3-7.5
Collecting and spreading manure	6.4	--
Binding sheaves	5.4-7.5	3.3-5.4
Uprooting sweet potatoes	3.5	3.1
Weeding	2.5-5.0	2.9
Plowing	4.6-6.8	--
Cleaning house	--	2.2
Child care	--	2.2
Threshing	--	4.2
Cutting grass with machete	--	5.0
Laundry work	--	3.4
Felling trees	7.5	--

Sources: Sources are FAO/WHO/UNU 1985, 76-78, 186-191; Durnin and Passmore 1967, 31, 66, 67, 72.

Notes: Rates in Durnin and Passmore given in kcal/min were converted into multiples of BMR, using kcal per min of a 65 kg man and a 55 kg woman of average build (31).

agriculture and nonagriculture (Fogel and Floud 1994; Fogel 1991). Although national food-balance sheets, such as those constructed by Toutain (1971) for France over the period 1781-1952, provide mean values of per capita caloric consumption, they do not produce estimates of the size distribution of calories. In principle it is possible to construct size distributions of calories from household consumption surveys. Inasmuch as most of these surveys during the nineteenth century were focused on the lower classes, in order to make use of them it is necessary to know from what centiles of either the national caloric or the national income distribution the surveyed households were drawn.

Three factors make it possible to estimate the size distributions of calories from the patchy evidence available to historians. First, studies covering a wide range of countries indicate that distributions of calories are well described by the lognormal distribution. Second, the variation in the distribution of calories (as measured by the coefficient of variation [$s/\bar{X}$] or the Gini [G] ratio) is far more limited than the distribution of income. In contradistinction to income, the bottom tail of the caloric distribution is sharply restricted by the requirement for basal metabolism and the prevailing death rate. The bottom end is also constrained by the requirement that the energy available to the agricultural labor force is sufficient to produce the agricultural output. At the top end it is restricted by the human capacity to use energy and the distribution of body builds. Consequently, the extent of the inequality of caloric distributions is pretty well bounded by $0.4 \geq (s/\bar{X}) \geq 0.2$ ($0.22 \geq G \geq 0.11$) (FAO 1977; U.S. National Center for Health Statistics 1977; Lipton 1983; Aitchison and Brown 1966). Third, when the mean is known, the coefficient of variation (which together with the mean determines the distribution) can be estimated from either tail of the distribution. Even in places and times where little is known about ordinary people, there is a relative abundance of information about the rich. At the bottom end information on mortality rates and on the energy requirement of the agricultural labor force rather tightly constrain the proportion of the distribution that lies below BMR.

1.2. Estimates and Implications of the Levels and Distributions of Caloric Consumption in Britain and France Near the End of the Ancien Règime

Due to the work of Toutain (1971) we have a series of estimates of average caloric consumption for France that extend back to c.1785. His estimates, which are derived from national food balance sheets, imply that the average caloric consumption in France on the eve of the French Revolution was about 1,753 kcals per capita or about 2,290 kcals per consuming unit. This is a very low level of energy consumption, ranking France c.1785 with such impoverished countries today as Pakistan and Rwanda (World Bank 1987).

Work on the English caloric consumption has lagged behind that of France. Oddy (1990) and Shammas (1990), using the budgets of rural households collected by Davies for c.1790 and Eden for c.1794 (Stigler 1954), have estimated that the mean daily caloric consumption was in the neighborhood of 2,100 kcals per capita. Standardizing for age and gender and allowing for the place of these rural households in the English size distribution of income developed by Lindert and Williamson (1982; cf. Fogel 1993b) for the mid-eighteenth century, this figure implies a national average daily caloric consumption of about 2,700 kcals per consuming unit.

Recent work by agricultural historians summarized by Holderness (1989) and Allen (1994) have yielded estimates of English agricultural output at half century intervals between 1700 and 1850. The procedures used to convert these estimates into a national food balance sheet are described in Fogel and Floud (1994). Since work on the refinement of these procedures is still in progress, the estimates of average daily caloric consumption presented here are provisional and are only rough indicators of the possible course of consumption. They should be treated as illustrative, suggesting the orders of magnitude that are involved and posing provisional hypotheses aimed at stimulating future research. These estimates are as follows:

	kcals per capita	**kcals per consuming unit**
1700	1,802	2,365
1750	1,911	2,508
1800	2,346	3,079
1850	2,235	2,933

If we interpolate this series geometrically, the estimate of kcals per consuming unit in 1790 is 2,955, which is about 255 kcals more than the figure obtained from the household studies.

One implication of the French and British estimates of mean daily caloric consumption is that mature adults of the late eighteenth century must have been very small by current standards. Today the typical American males in his early thirties is about 177 cm (69.7 inches) tall and weighs about 78 kg (172 lbs) (USDHHS 1987). Such a male requires daily about 1,794 kcal for basal metabolism and a total of 2,279 kcal for baseline maintenance. If either the British or the French had been that large during the eighteenth century, virtually all of the energy produced by their food supplies would have been required for maintenance and hardly any would fhave been available to sustain work. To have the energy necessary to produce the national products of these two countries c.1700, the typical adult male must have been quite short and very light.

This inference is supported by data on stature and weight which have been collected for European nations. Table 2 provides estimates of final heights of adult males who reached maturity between 1750 and 1875. It shows that during the eighteenth and nineteenth centuries Europeans were severely stunted by modern standards (cf. line 6 of Table 2). Estimates of weights for European nations before 1860 are much more patchy. Those which are available, mostly inferential, suggest that c.1790 the average weight of English males in their thirties was about 61 kg (134 lbs), which is about 20 percent below current levels. The corresponding figure for French males c.1790 may have been only about 50kg (about 110 lbs), which is about a third below current standards.

Table 3 displays the caloric distribution for England and France implied by the available evidence.[5] It shows the exceedingly low level of work capacity permitted by the food supply in France and England c.1790, even after allowing for the reduced requirements for maintenance because of small stature and bodymass (cf. Freudenberger and Cummins 1976). In France the bottom 10 percent of the labor force lacked the energy for regular work and the next 10 percent had enough energy for less than 3 hours of light work daily (0.52 hours of heavy work). Although the English situation was somewhat better, the bottom 3 percent of its labor force lacked the energy for any work, but the balance of the bottom 20 percent had enough energy for about 6 hours of light work (1.09 hours of heavy work) each day.

Table 2

Estimated Average Final Heights of Men Who Reached Maturity Between 1750 and 1875 in Six European Populations, by Quarter Centuries (cm)

	(1) Date of maturity by century and quarter	(2) Great Britain	(3) Norway	(4) Sweden	(5) France	(6) Denmark	(7) Hungary
1.	18-III	165.9	163.9	168.1	--	--	168.7
2.	18-IV	167.9	--	166.7	163.0	165.7	165.8
3.	19-I	168.0	--	166.7	164.3	165.4	163.9
4.	19-II	171.6	--	168.0	165.2	166.8	164.2
5.	19-III	169.3	168.6	169.5	165.6	165.3	--
6.	20-III	175.0	178.3	177.6	172.0	176.0	170.9

Sources: Fogel 1987, Table 7 for all columns except 5. Column 5: Rows 3-5 were computed from Meerton 1989 as amended by Weir (1993), with 0.9 cm added to allow for additional growth between age 20 and maturity (Gould 1869, pp. 104-105; cf. Friedman 1982, p. 510, n. 14). The entry to row 2 is derived from a linear extrapolation of Meerton's data for 1815-1836 back to 1788, with 0.9 cm added for additional growth between age 20 and maturity. The entry in row 6 is from Fogel 1987, Table 7.

Table 3

A Comparison of the Probable French and English Distributions of the Daily Consumption of Kcals per Consuming Unit Toward the End of the Eighteenth Century

		A		B	
		France c. 1785 $\bar{X}$ = 2,290 ($s/\bar{X}$) = 0.3		England c. 1790 $\bar{X}$ = 2,700 ($s/\bar{X}$) = 0.3	
	Decile (1)	Daily kcal consumption (2)	Cumulative % (3)	Daily kcal consumption (4)	Cumulative % (5)
1.	Highest	3,672	100	4,329	100
2.	Ninth	2,981	84	3,514	84
3.	Eighth	2,676	71	3,155	71
4.	Seventh	2,457	59	2,897	59
5.	Sixth	2,276	48	2,684	48
6.	Fifth	2,114	38	2,492	38
7.	Fourth	1,958	29	2,309	29
8.	Third	1,798	21	2,120	21
9.	Second	1,614	13	1,903	13
10.	First	1,310	6	1,545	6

Sources and procedures: See Fogel 1993b.

Table 3 also points up the problem with the assumption that for *ancien régime* populations, a caloric intake that averaged 2,000 kcal per capita (2,600 per consuming unit) daily was adequate (Livi-Bacci 1990). That average level of consumption falls between the levels experienced by the French and the English c.1790. In populations experiencing such low levels of average consumption, the bottom 20 percent subsisted on such poor diets that they were effectively excluded from the labor force with many of them lacking the energy even for a few hours of strolling. That appears to be the principal factor explaining why beggars constituted as much as a fifth of the populations of *ancien régimes* (Goubert 1973; Cipolla 1980; Laslett 1984). Even the majority of those in the top 50 percent of the caloric distribution were so stunted (height below U.S. standards) and wasted (weight below U.S. standards) that they were at substantially higher risk of incurring chronic health conditions and of premature mortality (see section 1.4, below).

1.3. Stature and Body Mass Indexes as Indicators of Secular Trends in Morbidity and Mortality

Extensive clinical and epidemiological studies over the past two decades have shown that height at given ages, weight at given ages, and weight-for-height (a body mass index) are effective predictors of the risk of morbidity and mortality (see the summaries in Fogel 1993b; Osmani 1992; and Fogel, Costa, and Kim 1994; cf. Heywood 1983; Waaler 1984; Martorell 1985). Height and body mass indexes measure different aspects of malnutrition and health. Height is a net rather than a gross measure of nutrition. Moreover, although changes in height during the growing years are sensitive to current levels of nutrition, mean final height reflects the accumulated past nutritional experience of individuals over all of their growing years including the fetal period. Thus, it follows that when final heights are used to explain differences in adult mortality rates, they reveal the effect, not of adult levels of nutrition on adult mortality rates, but of nutritional levels during infancy, childhood, and adolescence on adult mortality rates. A weight-for-height index, on the other hand, reflects primarily the current nutritional status. It is also a net measure in the sense that a body mass index (BMI) reflects the balance between intakes and the claims on those intakes. The most widely used body mass index is weight measured in kilograms divided by height measured in meters squared (kg/m^2), which is sometimes called the Quetelet index. Although height is determined by the cumulative nutritional status during an entire developmental age span, the BMI fluctuates with the current balance between nutrient intakes and energy demands. A person whose height is short relative to the modern U.S. or West European standard is referred to as "stunted." Those with low BMI's are referred to as "wasted."

The predictive power of height and body mass indexes with respect to morbidity and mortality are indicated by Figures 1 and 2. Part A of Figure 1 reproduces a diagram by Waaler (1984). It shows that short Norwegian men aged 40-59 at risk between 1963 and 1979 were much more likely to die than tall men. Indeed, the risk of mortality for men with heights of 165 cm (65.0 inches) was on average 71 percent greater than that of men who measure 182.5 cm (71.9 inches). Part B shows that height is also an important predictor of the relative likelihood that men aged 23-49 would be rejected from the Union Army during 1861-1865 because of chronic diseases. Despite significant differences in mean heights, ethnicities, environmental circumstances, the array and severity of diseases, and time, the functional relationship between height and relative risk are strikingly similar.

Waaler (1984) has also studied the relationship in Norway between BMI and the risk of death in a sample of 1.8 million individuals. Curves summarizing his findings are shown in Figure 2 for both men and women. Although the observed values of the BMI (kg/m^2) ranged between 17 and 39, over 90 percent of the males had BMIs within the range 21-29. Within the range 23-27, the curve is relatively flat, with the relative risk of mortality hovering close to 1.0. However, at BMIs of less than 21 and over 29, the risk of death rises quite sharply as the BMI moves away from its mean value. It will be noticed that the BMI curves are much more symmetrical than the height curves in Figure 1, which indicates that high BMIs are as risky as low ones.

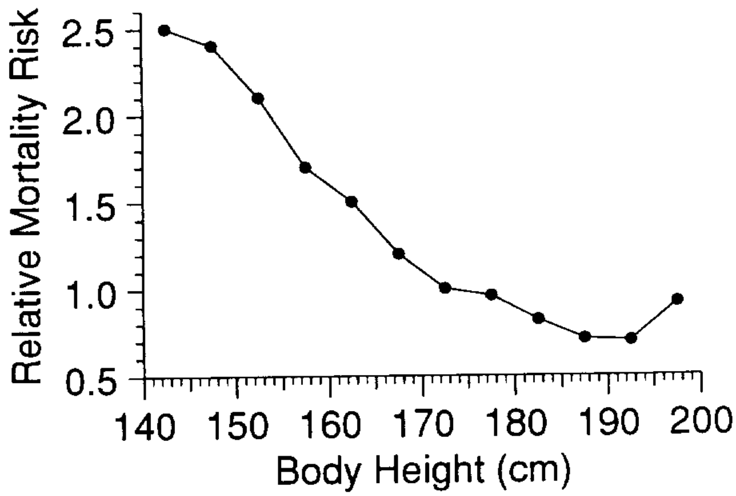
Adult height and the BMI measure different aspects of nutritional status. Not only is stunting due to malnutrition during developmental ages, but it appears that most stunting occurs under age 3, after which even badly stunted children generally move along a given height centile, that is, develop without incurring further height deficits (Tanner 1982; Billewicz and MacGregor 1982; Horton 1984; Martorell 1985). Second, no matter how badly stunted an adult might be, it is still possible to have an optimum (or good) weight for that

FIGURE 1

Comparison of the Relationship between Body Height and Relative Risk in Two Populations

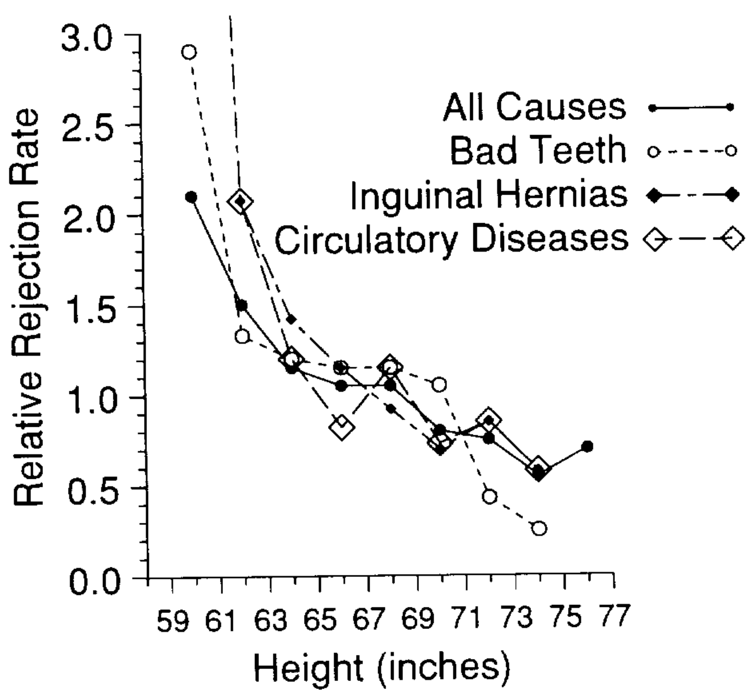
PART A

Relative Mortality Risk among Norwegian Men Aged 40-59, between 1963 and 1979



PART B

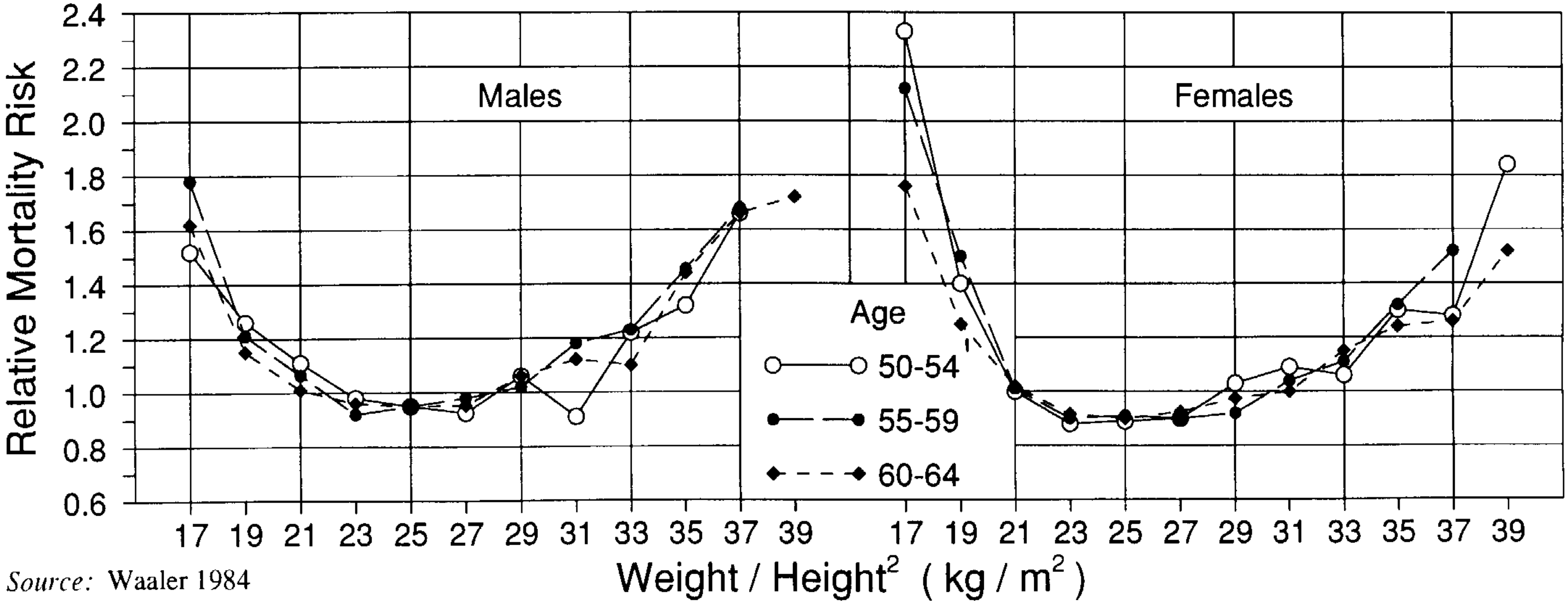
Relative Rejection Rates for Chronic Conditions in a Sample of 4,245 Men Aged 23-49, Examined for the Union Army



Sources: Part A: Waaler 1984, Part B: Fogel 1993b

FIGURE 2

Relationship between BMI and Prospective Risk among Norwegian Adults
Aged 50-64 at Risk (1963-1979)



Source: Waaler 1984

height. Thus, for example, a Norwegian male stunted by two inches during his developmental ages could still have had a normal risk if his BMI was about 26.

The fact that even badly stunted populations may have quite normal BMIs reflects the capacity of human beings to adapt their behavior to the limitations of their food supply. Adaptation takes place in three dimensions. Small people have lower basal metabolism, because less energy is needed to maintain body temperature and sustain the function of vital organs. Small people need less food and hence, require less energy to consume their food and for vital hygiene. The third aspect of adaptation comes in the curtailment of work and discretionary activity. If a small (56 kg) man confined himself to a few hours of light work each day, he could remain in energy balance and maintain his BMI at a satisfactory level with as little as 2,000 or 2,100 kcals. However, a larger man (79 kg) engaged in heavy work for 8 hours per day would require about 4,030 kcals to maintain his energy balance at a BMI of 24 (FAO/WHO/UNU 1985).

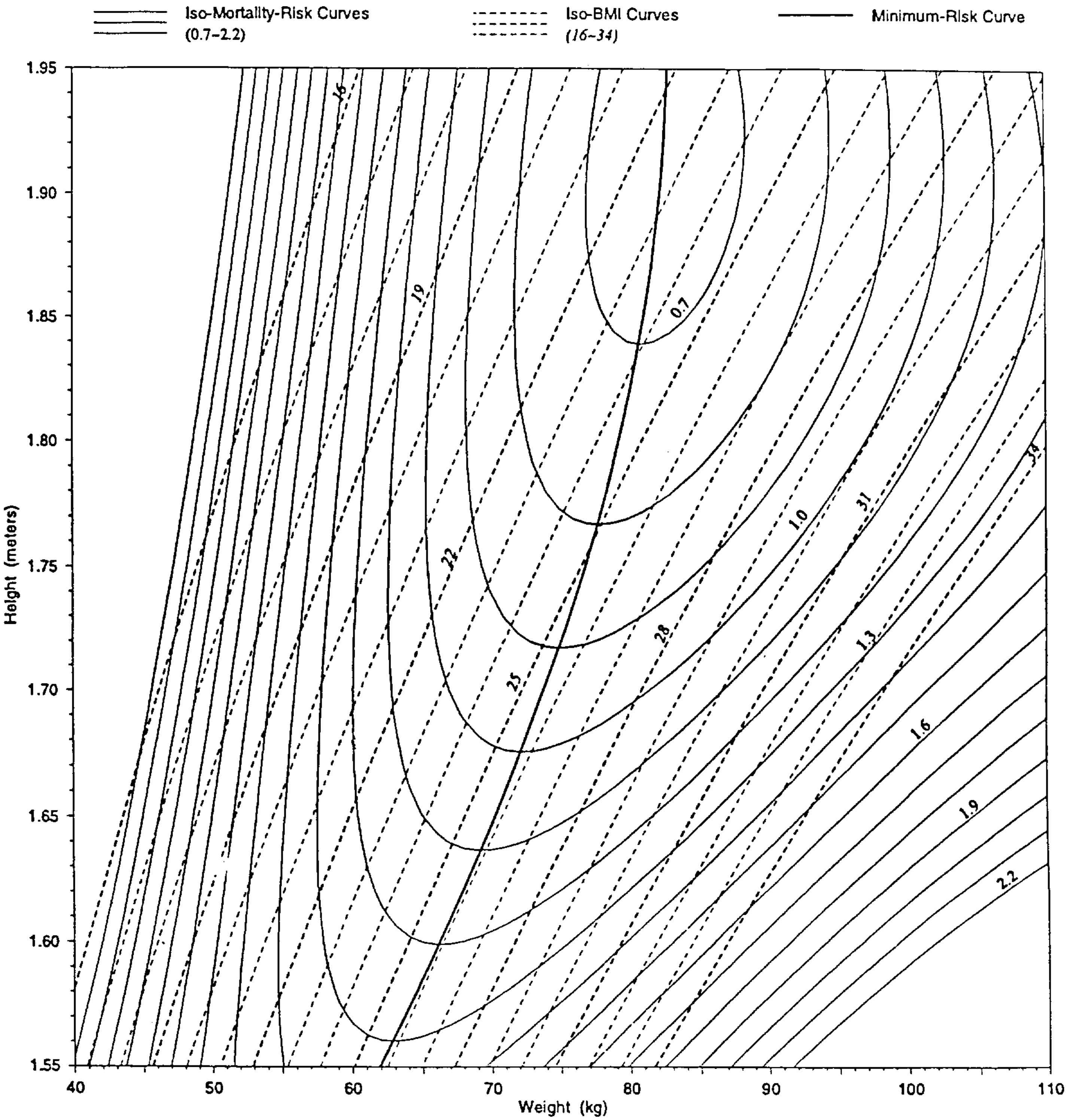
Although Figures 1 and 2 are revealing, neither one singly, nor both together, are sufficient to shed light on the debate over whether moderate stunting impairs health when weight-for-height is adequate, since Figure 1 is not controlled for weight and Figure 2 is only partially controlled for height (Fogel 1987; Fogel and Floud 1994). To get at the "small-but-healthy" (Seckler 1982) issue one needs an iso-mortality surface that relates the risk of death to both height and weight simultaneously. Such a surface, presented in Figure 3, was fitted to Waaler's data by a procedure described elsewhere (Fogel 1993b, Kim 1993). Transecting the iso-mortality map are lines which give the locus of BMI between 16 and 34, and a curve giving the weights that minimize risk at each height.

Figure 3 shows that even when body weight is maintained at what Figure 2 indicates is an "ideal" level (BMI = 25), short men are at substantially greater risk of death than tall men. Thus, an adult male with a BMI of 25 who is 164 cm tall is at about 55 percent greater risk of death than a male at 183 cm who also has a BMI of 25. Figure 3 also shows that the "ideal" BMI (the BMI that minimizes the risk of death) varies with height. A BMI of 25 is "ideal" for men in the neighborhood of 176 cm, but for tall men (greater than 183 cm) the ideal BMI is between 22 and 24, while for short men (under 168 cm) the "ideal" BMI is about 26.

Before using Waaler surfaces to evaluate the relationship between chronic malnutrition and the secular

Figure 3

Iso-Mortality Curves of Relative Risk
for Height and Weight Among Norwegian Males Aged 50~64



All risks are measured relative to the average risk of mortality (calculated over all heights and weights) among Norwegian males aged 50-64.

decline in mortality rates since 1700, several issues in the interpretation of that figure need to be addressed. First, it is important to understand the physiological foundation for the predictive capacity of Waaler surfaces and curves. Although research in this area is still developing rapidly and some of the new findings are yet to be confirmed, variations in height and weight appear to be associated with variations in the chemical composition of the tissues that make up the organs of the body, in the quality of electrical transmission across membranes, and in the functioning of the endrocrine system and other vital systems. Stunting and other physiological impairments that take place in utero or in early childhood are sometimes promptly visible as in the cases of Fetal Alcohol Syndrome and severe protein calorie malnutrition, both of which can lead to a permanent impairment of central nervous system function. Other physiological impairment caused by malnutrition in utero or early childhood may not show up until middle and late ages, when they increase the risk of incurring such conditions as coronary heart disease, hypertension, stroke, diabetes, and autoimmune thyroiditis. Persistent malnutrition at any point in the life cycle can produce severe physiological dysfunctions. In the case of the respiratory system, for example, there is not only decreased muscle mass and strength but also impaired ventilatory drive, biochemical changes in the connective system, and electrolyte abnormalities (Robins, Cotran, and Kumar 1984; Martorell, Rivera, and Kaplowitz 1990; Barker 1993; McMahon and Bristrian 1990; cf. Fogel 1994).

Second, since an individual's height cannot be varied by changes in nutrition after maturity, adults can move to a more desirable BMI only by changing weight. I, therefore, interpret the $\underline{X}$ axis as a measure of the effect of the current nutritional status of mature males on adult mortality rates. Moreover, since most stunting takes place below age 3 (Tanner 1982; Horton 1984; Martorell 1985; Steckel 1986), I interpret the $\underline{Y}$ axis as a measure of the effect of nutritional deprivation in utero or early in childhood on the risk of mortality at middle and late ages (cf. Tanner 1982; Steckel 1987; Fogel, Galantine and Manning 1992, chs. 42 and 47).

Third, in applying Figure 3 to the evaluation of secular trends in nutrition and mortality I assume that for Europeans environmental factors have been decisive in explaining the secular increase in heights, not only for population means, but also for individuals in particular families. The reasonableness of this assumption becomes evident when one considers the issue of shortness. If shortness is defined as a given number of S.D.s below a changing mean (i.e. short is 2 S.D.s below the mean, whether the mean is 164 cm or 183 cm), then genetic and environmental factors may be difficult to disentangle. If, however, shortness is defined in absolute terms, say as applying to all males with heights below 168 cm, then it is quite clear that most shortness in Europe and America during the eighteenth and much of the nineteenth centuries was determined by environmental rather than genetic factors.

The point at issue can be clarified by considering the experience of the Netherlands. Shortness has virtually disappeared from that country during the past century and a half. Today, less than 2 percent of young adult males are below 168 cm, but in c. 1855 about two-thirds were below that height. Since there has been little change in the gene pool of the Dutch during the period, it must have been changes in environmental circumstances, nutrition, and health that eliminated about 95 percent of all short males from the Dutch population (Van Wieringen 1986; Fogel 1987). Given current growth rates in the mean final height of the Netherlands, the remaining men shorter than 168 cm may yet be virtually eliminated from the Dutch population.

The Dutch case illustrates the general secular pattern of physical growth in the nations of Western Europe. The secular increase in mean final heights, which ranged between 10 and 20 centimeters (between 4 and 8 inches) over the past 200 years, cannot be attributed to natural selection or genetic drift, since these processes require much longer time spans. Nor can it be attributed to heterosis (hybrid vigor) because the populations in question have remained relatively homogeneous and because the effects of heterosis in human populations have been shown both empirically and theoretically to be quite small (Cavalli-Sforza and Bodmer 1971; Damon 1965; Van Wieringen 1978; Fogel et al. 1983; Martorell 1985; Mueller 1986). Only the top 6 percent of the Dutch height distribution of c. 1855 overlaps with the bottom 6 percent of the current distribution of final heights. Since the Dutch mean is still increasing, and we do not yet know the maximum mean genetically obtainable (often referred to as the genetic potential), it may well be that even the 6 percent overlap between the distribution of final heights in the c. 1855 generation and that of the latest generation will be cut in the next few decades, perhaps by as much as half.

Fourth, even if the Norwegian iso-mortality surface is applicable to European populations generally, the surface may not have been stable over time. Since height-specific and weight-specific mortality rates are measured relative to the average death rate for the population as a whole, short-term shifts in average death rates by themselves will not necessarily shift the surface. However, fundamental shifts in environment, including changes in medical technology, may change the risk surface.[6]

1.4 How Variations in Body Size Brought the Population and the Food Supply into Balance and Determined the Level of Mortality

The implication of energy cost accounting permitted by the recent work of agricultural historians is that to have the energy necessary to produce the national products of England and France c.1700, the typical adult male must have been quite short and very light, weighing perhaps 25 to 35 percent less than his American counterpart today. How Europeans of the past may have adapted their body size to accommodate their food supply is illustrated by Table 4, which compares the estimated average daily consumption of calories in England and Wales in 1700 and 1800 by two economic sectors: agriculture and everything else. Within each sector the estimated amount of dietary energy required for work is also shown. Line 3 presents a measure of the efficiency of the agricultural sector in the production of dietary energy. That measure is the number of calories of food output per calorie of work input.

Column 1 of the table presents the situation in 1800, when kcals available for consumption were relatively high by prevailing European standards (about 3,079 per consuming unit daily), when adult male stature made the British the tallest national population in Europe (168 cm or 66.1 inches at maturity) and relatively heavy by the prevailing European standards, averaging about 63.5 kg (about 140 pounds) at prime working ages which implies a BMI of about 22.5. Food was abundant because in addition to a substantial domestic production Britain imported about 5 percent of its dietary consumption. However, as column 1 indicates, British agriculture was quite productive. English and Welsh farmers produced 21.4 calories of food output (net of seeds, feed, inventory losses, etc.) for each calorie of their work input. About 42 percent of this bountiful output was consumed by the families of the agriculturalists (8,722 ÷ 20,559 ≈ 0.42).

The balance of their dietary output, together with some food imports, were consumed by the

Table 4

A Comparison of the Average Daily Uses of Dietary Energy in England and Wales in 1700 and 1800 (all lines in millions of kcals, except 3)

	1 1800	2 1700	3 1700 counter-factual
1. Total daily dietary energy consumed (production plus net imports)	21,480	10,498	7,825
2. Energy used to produce agricultural output	959	515	378
3. Energy productivity in agriculture (the output/input ratio of dietary energy)	21.4	20.7	20.7
4. Energy consumed in the agricultural sector	8,722	6,076	5,772
5. Energy consumed outside of the agricultural sector	12,758	4,422	2,053
6. Energy used to produce nonagricultural output	1,397	444	0

Note: See Fogel 1991 for a discussion of the sources and procedures involved in the construction of this table.

nonagricultural sector, which constituted about 64 percent of the English population in 1801 (Wrigley 1987, p. 170). Although food consumption per capita was about 8 percent lower in this sector than in agriculture, most of the difference was explained by the greater caloric demands of agricultural labor.[7] Food was so abundant that even the English paupers and vagrants, who accounted for about 12 percent of the population c.1800 (Lindert and Williamson 1982), had about 3 times as much energy for begging and other activities beyond maintenance as did their French counterparts (Fogel and Floud 1994).

The food situation was much tighter in 1700, when only about 2,365 kcals were available daily per consuming unit. The adjustment to the lower food supply was made in three ways. First, compared to 1800 the share of dietary energy made available to the nonagricultural sector in 1700 was lower by nearly two-thirds, a level that was maintained partly by constraining the share of the labor force engaged outside of agriculture. Second, the amount of energy available for work per equivalent adult worker was kept low both inside and outside of agriculture, although the reduction was somewhat greater outside of agriculture. Third, the energy required for basal metabolism and maintenance was low because body size was small. Compared with 1800, adult heights of males of 1700 were down by 5 cm, their BMI was 20 instead of 22.5, and their weights were down by about 10 kg. As a result of such constriction of the average body size of the population, the number of calories required for maintenance was reduced by 170 kcal per consuming unit daily.

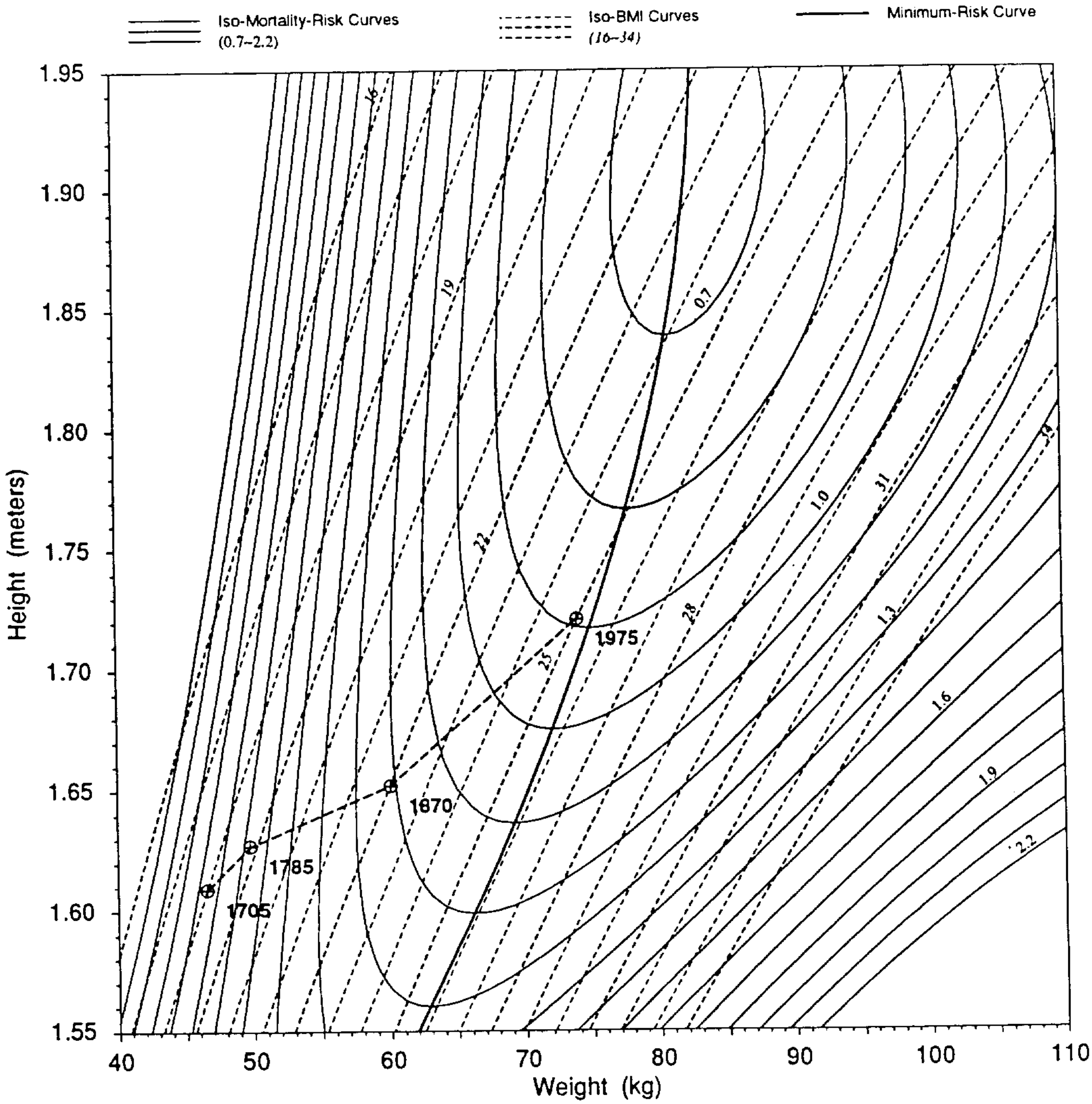
The last figure may seem rather small, accounting for just a quarter ($170 \div 714 \approx 0.24$) of the total shortfall in daily caloric consumption, so small that it may seem to undermine the proposition that variations in body size were a principal means of adjusting the population to variations in the food supply. Nevertheless, further consideration of Table 4 will sustain the proposition. The condition for a population to be in equilibrium with its food supply at a given level of consumption is that the labor input (measured in calories of work) is large enough to produce the requisite amount of food (also measured in calories). Moreover, a given reduction in calories required for maintenance will have a multiplied effect on the number of calories made available for work. The multiplier is the inverse of the labor force participation rate. Since only about 35 percent of equivalent adults were in the labor force, the daily gain in kcals for work was, not 170 per equivalent adult worker, but 485 kcals per equivalent adult worker.

The importance of the last point is indicated by considering columns 2 and 3 of Table 4. Column 2 shows that the daily total of dietary energy used for work in 1700 was 959 million kcals, with 515 million expended in agriculture and the balance in nonagriculture. Column 3 indicates what would have happened if all the other adjustments had been made but body size remained at the 1800 level, so that maintenance requirements were unchanged. The first thing to note is that energy available for food production would have declined by 27 percent. Assuming the same input/output ratio, the national supply of dietary energy would have declined to 7,825 million kcal, of which nearly three quarters would have been consumed within the agricultural sector. The residual available for nonagriculture would hardly have covered the maintenance requirements of that sector, leaving zero energy for work in nonagriculture. In this example, the failure to have constrained body size would have reduced the energy for work by about 61 percent $[1-(378 \div 959) \approx 0.61]$.[8]

Varying body size was a universal way that the chronically malnourished populations of Europe responded to food constraints. Such variation in height is evident in Table 2 and has been discussed in much more detail for England by Floud, Wachter, and Gregory (1990) and for Hungary by Komlos (1990). Some may want to debate whether the size mechanism was more important than variations in fertility in equating population and the food supply. That interesting question should be pursued, but here I want to focus on the implication of the size mechanism for the explanation of the secular decline in mortality.[9]

Figure 4 superimposes rough estimates of heights and weights in France at 4 dates on a Waaler surface. In 1705 the food supply in France was even lower than in Britain so that it was necessary to keep body mass even lower than in Britain. Circa 1705 the French are estimated to have achieved equilibrium with their food supply at a height of about 161 cm and a BMI of about 18. Over the next 270 years the food supply expanded with sufficient rapidity so that both the height and the weight of adult males increased. However, weight appears to have increased more rapidly than height during the first 165 years. Figure 4 indicates that it was factors associated with the gain in BMI that accounted for most of the reduction in the risk of mortality before 1870. After 1870, factors associated with the gain in height explain most of the additional mortality decline predicted by Figure 4.

FIGURE 4
Iso-Mortality Curves of Relative Risk for Height and Weight Among Norwegian Males Aged 50-64, With a Plot of the Estimated French Height and Weight at Four Dates



There is another implication of Figure 4 that is worth making explicit. If the relative risks of mortality in Figure 4 are standardized on the French crude death rate of c.1785, one obtains the following time series of crude death rates (per thousand):

	Estimated from Figure 4	From registrations or samples
c.1705	40	n.a.
c.1785	36	36
c.1870	26	25
c.1975	19	11

It thus appears that while factors associated with height and BMI jointly explain about 90 percent of the decline in French mortality rates over the period between c.1785 and c.1870, they only explain about 50 percent of the decline in mortality rates during the past century. Increases in body size continued to be a major indicator of improved life expectation among persons of relatively good nutritional status, but during the last century factors other than those which act through height and BMI became increasingly important.

The analysis in this section points to the misleading nature of the concept of subsistence as Malthus originally used it and as it is still widely used today. Subsistence is not located at the edge of a nutritional cliff, beyond which lies demographic disaster. The evidence outlined in the paper implies that rather than one level of subsistence, there are numerous levels at which a population and a food supply can be in equilibrium, in the sense that they can be indefinitely sustained. However, some levels will have smaller people and higher "normal" (non-crisis) mortality than others. Moreover, with a given population and technology one can alter body size and mortality by changing the allocation of labor between agriculture and other sectors. Thus, the larger the share of the labor force that is in agriculture, cet. par., the larger the share of caloric production that can be devoted to baseline maintenance.[10]

Although there were a wide range of levels at which the population and the food supply could have been in equilibrium, not all of these equilibria were equally desirable. Some equilibria left those in the bottom portion of the caloric distribution with so little energy that as much as a quarter of the potential labor force was effectively excluded from production. Such equilibria also made the population highly vulnerable to periodic breakdowns in the food distribution system (famines), although chronic malnutrition was responsible for many more deaths than the famines that called attention to the plight of the lower classes. Some equilibria required 80 percent or more of the labor force to work in the agricultural sector. However, a fairly high degree of diversification into trade and industry was possible even at fairly low levels of average caloric production. Although England in c.1700 and France in c.1785 had similar levels of caloric consumption per consuming unit, England was able to support about 45 percent of its labor force in nonagricultural pursuits, while France supported about 40 percent of its labor force in such pursuits. The critical difference was in the relatively high output/input ratio of dietary energy in England's agricultural sector (Wrigley 1987; O'Brien and Keyder 1978; Holderness 1989; Chartres 1985; Grantham 1990; Allen 1994; Fogel 1993b).

2. Malthusian Issues in the Late Twentieth Century: The Relevance of the Size Mechanism for the Evaluation of the Chronic Malnutrition, Work Capacity, Morbidity, and Mortality in Third World Countries

Malthusian theory still influences current policy debates. There are two sets of issues that could be considered within the analytical framework that has emerged from studies of the secular decline in mortality. One set of issues concerns policies aimed at improving conditions of life in the Third World. The other set of issues stems from the concern that the ecosystem is threatened by the doubling of the world's population between 1950 and 1990 and the expectation that the population will double again during the next half century (Livi-Bacci 1992; Economist 1990). Since threats to the ecosystem are treated at length elsewhere in this volume, the discussion here is limited to the first set of policy issues.

There are significant parallels between the level of malnutrition in Western Europe c. 1790 and the poor countries of the Third World during recent decades. The average daily caloric intake of low-income economies in 1990 was about 1,975 kcals per capita (World Bank 1992, p. 272), which falls between the levels of caloric consumption in France and Britain two centuries ago. The mean stature of males at maturity in these Third World countries was about 163 cm and the mean BMI was in the range of 18-22 (Eveleth and Tanner 1976), figures which again match those estimated for Western Europe near the beginning of the nineteenth century. Neither Malthus nor anyone else complained that the average body builds of their day were excessively low, although they did express alarm about the urban poor who were several centimeters shorter and who probably were about 10 kilograms lighter at maturity (Floud and Wachter 1982). Moreover, standards for the adequacy of the diet were set with reference to what was normally consumed by persons near the middle of the caloric distribution (Fogel 1989). However, given the work requirement and the exposure to disease, such diets led to equilibrium stature and BMI that substantially increased morbidity and death rates.

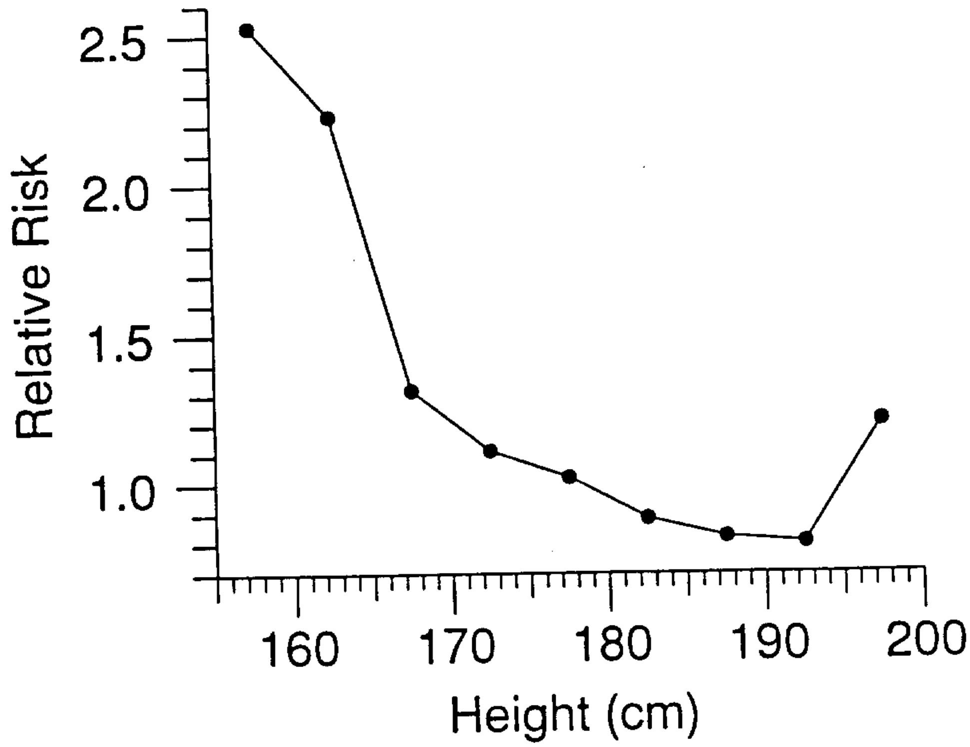
Poor body builds increased vulnerability to diseases, not just infectious diseases, but chronic diseases as well. This point is implicit in Figure 1b which shows that chronic conditions were much more frequent among short young men in the 1860s than among tall men. Figure 5 shows that the same relationship between ill health and stature exists among the males covered by the U.S. National Health Interview Surveys (NHIS) for 1985-1988. Stunting during developmental ages had a long reach and increased the likelihood that people would suffer from chronic diseases at middle and at late ages.

American males born during the second quarter of the nineteenth century were not only stunted by today's standards, but they were also wasted. Their BMIs at adult ages were about 15 percent lower than current U.S. levels (Fogel, Costa, and Kim 1994). The implication of the combined stunting and wasting is brought out by Figure 6 which presents a Waaler surface for morbidity estimated by Kim (1993) from NHIS data for 1985-1988.

The Waaler surface for risk from chronic conditions in Figure 6 is <u>similar</u> to the Norwegian surface for mortality (see Figure 4). The word similar was underscored because there are some differences that need to be noted. The isomorbidity curves in ill health rise more steeply than the isomortality curves as one moves away in either direction from the optimal weight curve. Furthermore, the optimal weight curve in Figure 6 usually lies about one iso-BMI curve to the right of the optimal weight curve computed from the Norwegian mortality data. Thus, both the Norwegian mortality data and the U.S. health data indicate that for men in the neighborhood of 1.60-1.65 meters the optimal BMI is in the range of 25 to 27. This is above current levels recommended by FAO/WHO/UNU (1985), falling into the lower ranges of overweight in that standard.

FIGURE 5

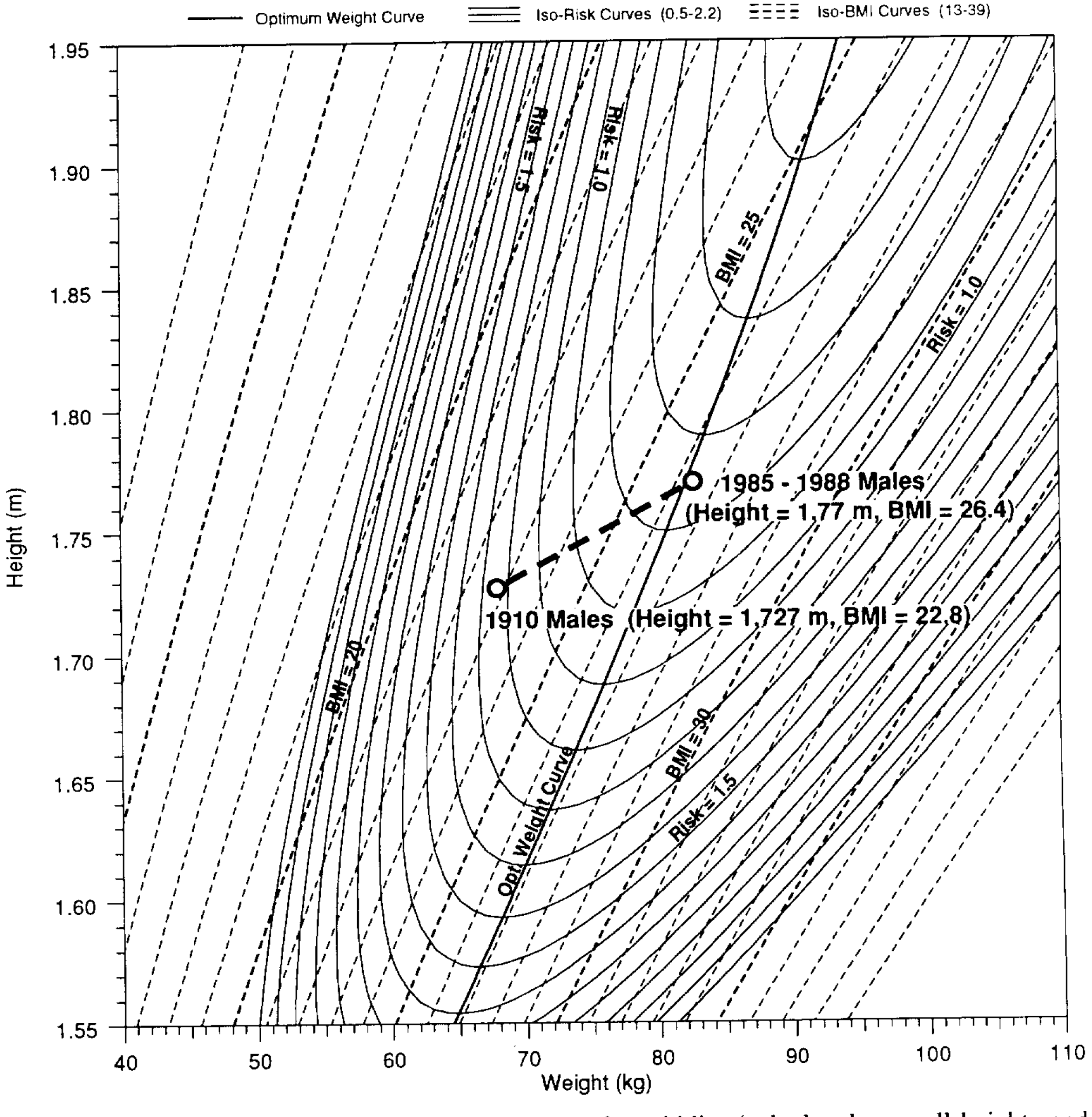
The Relationship between Height and Relative Risk of Ill Health in NHIS Veterans Aged 40-59



Source: Fogel, Costa, and Kim 1993

FIGURE 6

Health Improvement Predicted by NHIS 1985-1988 Health Surface



All risks are measured relative to the average risk of morbidity (calculated over all heights and weights) among NHIS 1985-1988 white males aged 45-64.

Source: Kim 1993

Figure 6 also presents the coordinates in height and BMI of Union Army veterans who were 65 or over in 1910 and of veterans (mainly of World War II) who were the same ages during 1985-1988. These coordinates predict a decline of about 35 percent in the prevalence of chronic disease among the two cohorts. About 61 percent of the predicted decline in ill health is due to factors associated with the increase in BMI and the balance is due to factors associated with increased stature.

The decline in the prevalence of chronic diseases indicated by Figure 6 is quite close to what actually occurred. Table 5 compares the prevalence of chronic diseases among Union Army men aged 65 and over in 1910 with two surveys of veterans of the same ages in the 1980s. That table indicates that heart disease was 2.9 times as prevalent, musculoskeletal and respiratory diseases were 1.6 times as prevalent, and digestive diseases were 4.7 times as prevalent among veterans aged 65 or over in 1910 as in 1985-1988. During the 7.6 decades separating the two groups, the prevalence of heart disease among the elderly declined at a rate of 12.8 per decade, while musculoskeletal and respiratory diseases each declined at a rate of 5.9 percent per decade.

The cohorts born between 1822 and 1845 not only suffered high rates of chronic conditions in old age, they also suffered high rates of chronic diseases at young adult ages (Fogel, Costa, and Kim 1994). Those who survived the deadly infectious diseases of childhood and adolescence were not freer of degenerative diseases, as some have suggested, but more afflicted. At ages 35-39 hernia rates, for example, were more than three times as prevalent in the 1860s as in the 1980s. Of special note is the much higher incidence of clubfoot in the 1860s, a birth anomaly which suggests that the uterus was far less safe for those awaiting birth than it is today. Nor is the idea that violence has increased borne out by the new data. As is indicated by the greater prevalence of deformities of the hand, and other injuries, the mid nineteenth century was filled with violence that is less often encountered today, particularly in the occupational realm.

Those who survived the killer contagious diseases of early and middle ages were more afflicted by degenerative chronic conditions at old ages in the 1910s than in the 1980s. Nearly 74 percent of the elderly Union Army veterans suffered from three or more disabling chronic conditions, which is much higher than the rate among elderly veterans in 1983 (Fogel, Costa, and Kim 1994). It may be true that there were less genetically frail persons among those who survived to age 65 in 1910 than there are today. If so, that genetic advantage was apparently offset by

Table 5

Comparison of the Prevalence of Chronic Conditions Among Union Army Veterans in 1910, Veterans in 1983 (Reporting whether they ever had specific chronic conditions), and Veterans in NHIS 1985-88 (Reporting whether they had specific chronic conditions during the preceding 12 months), Aged 65 and Above, Percentages

Disorder	1910 Union Army veterans[a]	1983 veterans[a]	Age-adjusted 1983 veterans[a]	NHIS 1985–88 veterans[a]
Musculoskeletal	67.7	47.9	47.2	42.5
Digestive	84.0	49.0	48.9	18.0
Hernia	34.5	27.3	26.7	6.6
Diarrhea	31.9	3.7	4.2	1.4
Genito-urinary	27.3	36.3	32.3	8.9
Central nervous,endocrine, Metabolic, or blood	24.2	29.9	29.1	12.6
Circulatory[b]	90.1	42.9	39.9	40.0
Heart	76.0	38.5	39.9	26.6
Varicose veins	38.5	8.7	8.3	5.3
Hemorroids[c]	44.4			7.2
Respiratory	42.2	29.8	28.1	26.5

[a] Prevailing rates of Union Army veterans are based on examinations by physicians. Those for the 1980s are based on self reporting. Comparison of the NHIS rates with those obtained from physicians' examinations in NHANES II indicates that use of self reported health conditions does not introduce a significant bias into the comparison. See the source for a more detailed discussion of possible biases and their magnitudes.

[b] Among veterans in 1983, the prevalence of all types of circulatory diseases will be underestimated because of under-reporting of hemorroids.

[c] The variable indictating if the 1983 veteran ever had hemorroids is unreliable.

Source: Fogel, Costa, and Kim 1993

a lifetime of socioeconomic and biomedical stress that left health in old age badly impaired and that sharply curtailed the life expectations of the elderly. During the 1910s the elderly died not from the infectious diseases that killed the great majority of their cohorts at relatively young ages but primarily from degenerative diseases which, at the two-digit level, are similar to the distribution of causes of death during the 1980s, except that deaths from neoplasms were lower and deaths from tuberculosis were higher than in the 1980s (cf. Preston 1976).

The provisional findings thus suggest that chronic conditions were far more prevalent throughout the life-cycle for those born between 1820 and 1850 than is suggested by the theory of the epidemiological transition. Reliance on causes-of-death information to characterize the epidemiology of the past has led to a significant misrepresentation of the distribution of health conditions among the living. It has also promoted the view that the epidemiology of chronic diseases is more separate from that of infectious diseases than may be the case.

Malthus's legacy to current discussions of population policy and malnutrition thus has two aspects, one of which is widely recognized. The other aspect, however, is more covert, although its influence on current policy discussions is powerful. The continued pressure of population against food resources is the acknowledged part of the Malthusian legacy. The recently published Second Report on the World Nutrition Situation (United Nations 1992), for example, concluded that one-third of the children of the Third World (184,000,000 children) were malnourished. The same report concludes that 40 percent of women of childbearing age in South and Southeast Asia are wasted (BMI below 18.5) and that between 15 and 20 percent of these women are stunted (height below 1.45m).

The other aspect of the Malthusian legacy is that malnutrition manifests itself primarily among the exceptional: In the starvation and excess mortality brought on by famines and prevalent among the ultra-poor of his day who lived in misery and vice. Malthus thought that persons near the middle of the social order, the sturdy agricultural laborer or the town artisan, were generally well fed, healthy, and lived normal lives. We now know, however, that famines accounted for less than 4 percent of the premature mortality of Malthus's age, and that the excess mortality of the ultra-poor (the bottom fifth of society) accounted for another sixth of premature mortality. About two-thirds of all premature mortality in Malthus's time came from the part of society that Malthus viewed as productive and healthy. Yet by current standards, even persons in the top half of the income distribution in Britain during the eighteenth century were stunted and wasted, suffered far more extensively from chronic diseases at young adult and middle ages than is true today, and died 30 years sooner than today.[11]

This aspect of the Malthusian legacy is embodied in such theses as "small-but-healthy" which holds that stunted or wasted individuals may not be more vulnerable to ill health and mortality than those who conform to the standards of the National Centers for Health Statistics (NCHS). The thesis also calls into doubt the proposition that stunting, in the absence of wasting, affects work capacity at adult ages. This Malthusian perspective has arisen partly because of the paucity of life-cycle data sets, especially in Third World countries, which caused investigators to focus only on the early years of the life span, searching for interaction between natal and infant measures of size and measures of health and work capacity later in childhood. Such studies generally picked up the effects of only exceedingly severe stunting and wasting (more than 2 S.D.s below average), missing the impact of more moderate size effects, many of which do not show up until later in life (Seckler 1980; Sukhatme 1981; Lipton 1983; cf. West et al. 1990).

However, the information reported in this paper indicates that stunting (most of which occurs before age 3) has a long reach, predicting chronic disease rates at young adult and later ages. Low BMI also predicts chronic diseases, both contemporaneously and in later ages. In both the Norwegian and the Union Army data, low BMI at middle ages predicts the odds of dying over long periods after measurement (Costa 1993). Other recently reported life-cycle interactions related to anthropometric measures include the finding that high blood pressure among men and women aged 46 to 54 is negatively related to their birth weight and positively related to placental weight. It has also been reported that mortality from ischaemic heart disease among men in late middle ages was positively related both to their birth weight and to their weight at age one (Barker 1991; cf. Elo and Preston 1992; Mackenbach 1992).

The higher prevalence of disabling chronic diseases (such as hernias, chronic diarrhea, arthritis, heart disease, and respiratory diseases) among stunted and underweight adults in the Third World has escaped attention because the relevant information on such conditions are not generally collected. But the existence of such a relationship in rich countries, both now and when they were much poorer than they are today, suggests that such conditions also exist in Third World countries.

Chronic diseases are not the only way that the existence of chronic malnutrition reduces the productivity of the labor force. When the mean amount of calories are as low as they are in the poor nations of the world, labor force participation rates and measures of labor productivity are bound to be low, especially when the hours of labor are not adjusted for the intensity of labor (see Fogel 1991). The point at issue here can be illustrated by considering the contribution of improved nutrition to the growth of per capita income in England between 1790 and 1980. Consideration of the issue starts with the first law of thermodynamics which applies as strictly to the human engine as to mechanical engines. Since, moreover, the overwhelming share of calories consumed among malnourished populations is required for BMR and essential maintenance, it is quite clear that in energy-poor populations, such as those of Europe during the second half of the eighteenth century, the typical individual in the labor force had relatively small amounts of energy available for work. This observation does not preclude the possibility that malnourished French peasants worked hard for relatively long hours at certain times of the year as at harvest time. Such work could have been sustained either by consuming more calories than normal during such periods, or by drawing on body mass to provide the needed energy. That level of work, however, could not have been sustained over the entire year. On average, the median individual in the French caloric distribution of 18-IV had only enough energy, over and above maintenance, to sustain regularly about 1.9 hours of heavy work or about 3.4 hours of moderate work per day (Fogel and Floud 1994).

It is quite clear, then, that the increase in the amount of calories available for work over the past 200 years must have made a nontrivial contribution to the growth rate of the per capita income of countries such as France and Great Britain. That contribution had two effects. First, it increased the labor force participation rate by bringing into the labor force the bottom 20 percent of the consuming units, who, even assuming highly stunted individuals and low BMIs, had only enough energy above maintenance for a few hours of strolling each day--about the amount needed for a career in begging--but less on average than that needed for just one hour of heavy manual labor.[12] Consequently, merely the elimination of the large class of paupers and beggars, which was accomplished in England mainly during the last half of the nineteenth century (Lindert and Williamson 1982 and 1983; Himmelfarb 1983; Williamson 1985), contributed significantly to the growth of national product. The increase in the labor force participation rate made possible by raising the nutrition of the bottom fifth of consuming units above the threshold required for work, by itself, contributed 0.11 percentage points to the annual British growth rate between 1780 and 1980 ($1.25^{0.005} - 1 = 0.0011$).

In addition to raising the labor force participation rate, the increased supply of calories raised the average consumption of calories by those in the labor force from 2,944 kcal per consuming unit in c. 1790 to 3,701 kcal per consuming unit in 1980. Of these amounts, 1,009 kcal were available for work in c. 1790 and 1,569 in 1980, so that calories available for work increased by about 56 percent during the past two centuries. We do not know exactly how this supply of energy was divided between discretionary activities and work c. 1790 but we do know that the pre-industrial and early-industrial routine had numerous holidays, absentee days, and short days (Thompson 1967; Landes 1969). If it is assumed that proportion of the available energy devoted to work has been unchanged between the end points of the period, then the increase in the amount of energy available for work contributed about 0.23 percentage points per annum to the annual growth rate of per capita income ($1.56^{0.0053} - 1 = 0.0023$).

Between 1780 and 1979, British per capita income grew at an annual rate of about 1.15 percent (Maddison 1982; Crafts 1985). Thus, in combination, bringing the ultra poor into the labor force and raising the energy available for work by those in the labor force, explains about 30 percent of the British growth in per capita income over the past two centuries.

At the present stage of research, the last figure should be considered more illustrative than substantive since it rests on two implicit assumptions that have yet to be explored adequately. The first is that the share of energy above maintenance allocated to work was the same in 1980 as in c. 1790. It is difficult to measure the extent or even the net direction of the bias due to this assumption. On the one hand absenteeism appears to have been much more frequent in the past than at present, due either to poor health or a lack of labor discipline (Landes 1969). On the other hand work weeks are shorter today than in the past and a large share of energy above maintenance may be devoted to recreation or other activities whose values are excluded from the national income accounts.[13]

To sum up this section: Populations of poor countries, in the past and today, have adapted to their low levels of average food consumption by keeping their body sizes low, by having a large proportion of the population that is excluded from effective labor, and by limiting the intensity of the labor of those who are effectively participating in the labor force. Although this is a feasible way of adjusting to the pressure of population on the food supply, it is a costly solution. It not only impedes economic growth but it undermines health by making individuals more vulnerable to killer infectious diseases, by greatly increasing the rates of chronic diseases among those who survive the acute infections, and by reducing life expectations at all stages of adult ages (cf. Sen 1993). Some may question the use of the experiences of the OECD nations, even if those experiences include periods when these nations were as poor as the poor nations of the Third World, on the ground that the NCHS growth standards do not apply. While that issue needs to be pursued further, it is important to note that recent studies of the growth patterns of affluent Indian children in seven different cities produced growth curves that conformed quite closely to the NCHS standard (Agarwal et al. 1991).

3. The New Population Issues

Between 1900 and 1950 U. S. life expectation at birth increased from 47 to 68 years. Then for the next two decades further progress in longevity came to a virtual halt. Although there were some minor changes in the age-specific death rates of both men and women, they had little impact on the joint expectation of life at birth. During this interregnum a number of thoughtful analysts reviewed the progress in mortality over the preceding century, pointing out why the century-long decline in mortality rates was unique and could not be repeated: Nearly all the gains that could be made from the elimination of death from infectious diseases below age 60 had been made. Short of a dramatic breakthrough biologically, it was doubtful that declines in mortality rates at old ages could be as large as those that had already transpired. Indeed, by the early 1960s there was some evidence of a relative deterioration in the mortality rates of persons aged 40 to 70 in a study of Western countries, which appeared to be due to the effects of smoking (Stolnitz 1956/57; Keyfitz 1977; Preston 1970).

It was not until the end of the 1970s that demographers became aware that a new decline in mortality was under way, concentrated this time at older ages. Evidence of a downturn in the death rates of the elderly was contained in medicare data which showed that beginning in 1968 and continuing through the end of the seventies, mortality rates at age 65 and over were declining by two percent per year, and the most rapid advances were concentrated among those aged 85 and older. This development was so unexpected by demographers and epidemiologist that it set off intense discussions, akin to those stimulated two decades earlier as population specialists became aware of the baby boom (Wilkin 1981). The new round of research focused not only on the explanation for the improvement in mortality rates but on how long the decline might continue and whether an increase in the burden of chronic disease was a necessary consequence of the increase in life expectation at older ages (Verbrugge 1984 and 1989; Wilson and Drury 1984; Svanborg 1988; Guralnik et al. 1989; Riley 1989 and 1990; Rothenberg and Koplan 1990).

The most far-reaching aspects of the discussion was the new debate over whether or not the life span (the ultimate length of the life of a species) is fixed, and if so how long the human life span was. In a celebrated paper Fries (1980), reasserted the prevailing gerontological view that although life expectation had increased from 47 to 73 during the twentieth century, the life span was fixed. On the assumption that the Gompertz curve (which relates the log of ${}_nQ_x$ to age) was linear at adult ages, he estimated that the life span was fixed at 85±7 years. Consequently age 85 was the upper limit of life expectation and it would be achieved by a rectangularization of the survivorship (l_x) curve: Virtually all deaths in a cohort would be compressed into a few years in the neighborhood of age 85. He also argued that movement of life expectation toward the ideal life span (85) would not increase the proportion of the elderly population that was disabled because the onset of chronic diseases could be postponed (the morbidity curve would also be rectangularized) through changes in lifestyle and biomedical interventions (cf. Olshansky et al. 1991).

That paper touched off a highly productive debate which is still in progress. One important aspect of his argument was that chronic diseases had not only replaced acute infectious diseases as the principal medical problem, but that these chronic conditions were independent of the acute infectious diseases. They were instead "problems of accelerated loss of organ reserve" (p.132), part of the natural process of senescence that preceded mortality. Since this upper limit of life was fixed at age 85±7 years, the most could be accomplished by lifestyle changes and medical intervention was the compression of morbidity against the rigid ceiling of 85±7 (cf. Fries 1983 and 1989).

Although the issues raised by Fries have not yet been resolved, much of the evidence accumulated by investigators during the last decade militates against the notion of a genetically fixed life span or, if it is fixed, suggests that the upper limit is well above 85. Vaupel's study of Danish twins indicates that genetic factors account for only about 30 percent of the variance in age of death (Vaupel 1991a). His study of Swedish males who lived to age 90 indicates that the death rate at that age has declined at a rate of about 1 percent per annum since 1950, a finding that is contradictory to the rectangularization of the survivorship curve (Vaupel 1991b). Two recent studies of insect populations (Carey et al. 1992; Curtsinger et al. 1992) indicated that variation in environmental conditions had a much larger effect on the life span than genetic factors and revealed no pattern suggestive of a fixed upper limit. Collectively, these studies do not rule out genetic factors but suggest something much less rigid than the genetic programming of absolute life spans: An emerging theory combines genetic susceptibility of various organs with cumulative insults as a result of exposure to risk.

Recent studies indicate that age-specific rates of chronic conditions above age 65 are generally falling, but they do not support the proposition that the span of years during which individuals will be afflicted by chronic diseases is being compressed. According to Manton, Corder, and Stallard (1993) the rate of disability among the elderly in the U. S. declined by 4.7 percent between 1982 and 1989. Put on a decade basis, this rate of decline is quite similar to the long-term rates of decline between 1910 and 1985-88 in chronic conditions among elderly veterans (Fogel, Costa, and Kim 1994). The finding is consistent with the growing body of evidence (reported in section 2, above) indicating that chronic diseases at later ages are, to a considerable degree, the result of exposure to infectious diseases and other types of biomedical and socioeconomic stress early in life. It is also consistent with the predicted decline of about 6 percent per decade in chronic diseases based on the Waaler surface in ill health displayed in Figure 6 (cf. Blair et al. 1989; Manton, Stallard, and Singer 1992; Manton and Soldo 1992).

Much of the current research is now focused on explaining the decline in chronic conditions. Part of the emerging explanation is a change in life styles, particularly the reduction in smoking, the improvement in nutrition, and the increase in exercise, which appear to be involved in reducing the prevalence of coronary heart disease and respiratory diseases. Another part of the explanation is the increasing effectiveness of medical intervention. This point is strikingly demonstrated by comparing the second and last columns of the line on hernias in Table 5, above. Prior to World War II hernias, once they occurred, were generally permanent, and often exceedingly painful conditions. However, by the 1980s about three-quarters of all veterans who ever had hernias were cured of them. Similar progress over the seven decades is indicated by the line on genito-urinary conditions, which shows that three-quarters of those who ever had such conditions were cured of them. Other areas where medical intervention has been highly effective include control of hypertension and reduction in the incidence of stroke, surgical removal of osteoarthritis, replacement of knee and hip joints, curing of cataracts, and chemotherapies that reduce the incidence of osteoporosis and heart disease (Manton, Corder, and Stallard 1993).[14]

The success in medical interventions combined with rising incomes has naturally led to a huge increase in the demand for medical services. Econometric estimates suggest a long-run income elasticity in the demand for medical services across OECD nations in the neighborhood of 1.5 and indicate that 90 percent of the variance in medical expenditures across OECD countries is explained by variations in income (Moore, Newman, and Fheili 1992). The rapidly growing level of demand, combined with the egalitarian policy of providing medical care at highly subsidized prices, has created the crisis in health care costs that is now such a focus of public policy debates across OECD nations, with various combinations of price and governmental rationing under consideration (Economist 1991; Newhouse 1992; Schwartz and Aaron 1991, Schieber, Poullier, and Greenwald 1993).

Whatever the eventual outcome of these policy debates, it is clear that we are in a much different world than that of Malthus. Instead of debating whether to provide food to paupers who might otherwise die, we are now debating how to distribute services that have proved successful in raising the quality of life of the aged and in extending life expectation. And we are now struggling with such entirely new ethical issues as whether it is right to restrict medical services that extend life of a low quality (Shuttleworth 1990; Wolfe 1986; Pellegrino 1993).

Growing opportunity to improve health at young ages, to reduce the incidence of chronic diseases at late ages, and to cure or alleviate the disabilities associated with chronic diseases raises two other post-Malthusian population issues. One is the impact of improved health on population size. A recent paper by Ahlburg and Vaupel (1990) pointed out that if mortality rates at older ages continue to decline at 2 percent per annum, the U.S. elderly population of 2050 would be 36 million larger than forecast by the Census Bureau. That possibility poses policy issues with respect to health care costs (because total medical costs may rise sharply even if cure rates continue to improve) and to pension costs (because the number of persons eligible for benefits under present proposed rules and of projected levels of compensation will become so large that outpayments will exceed planned reserves).

Some policymakers have sought to meet the pension problem by delaying retirement. Such schemes are based on the proposition that improved health will make it possible for more people to work past age 65. However, the recent findings on the secular improvement in health at older ages make it clear that worsening health is not the explanation for the steep decline since 1890 in labor force participation rates of males over 65.[15] As Costa (1993) has reported, the U.S. decline in participation rates of the elderly over the past century is largely explained by the rise in income and a decline in the income elasticity of retirement. It is also related to the vast increase in the supply and the quality of leisure-time activities for the laboring classes.

In Malthus's time, and down to the opening of this century, leisure was in very short supply in the OECD countries and, as Veblen pointed out (1934), it was conspicuously consumed by a small upper class. The typical person labored over 60 hours per week for wages and often had chores at home which consumed an additional 10 or 12 hours. Aside from sleep, eating, and hygiene, such workers usually had barely 2 hours a day for leisure. Although opera, theater, and ballet were available, they were too expensive to be consumed by the laboring classes.

Over the twentieth century, hours of work have fallen by nearly half for typical workers. Ironically, those in the top decile of the income distribution have not shared much in this gain of leisure since the highly paid professionals and businessmen who populate the top decile work closer to the nineteenth-century standard of 3,200 hours per year than the current working-class standard of about 1,800 hours. There has also been a vast increase in the supply of leisure-time activities--movies, radio, television, amusement parks, participant and spectator sports, travel--and a decline in the price of such activities. Many firms cater especially to the tastes of the elderly, offering reduced prices and special opportunities. As a result, the typical worker spends two-thirds as much time in leisure activities as in work and looks forward to retirement (Fogel 1992a and 1993a).

Given the growing and income-inelastic demand for leisure that characterizes the post-Malthusian milieu of the OECD nations, it remains to be seen to what extent the demand for leisure and retirement can be throttled. Policymakers may encounter as much resistance to efforts to reduce the implicit subsidies for leisure as they have had recently in raising the taxes on work.

* * *

The escape from hunger, poor health, and premature death which began in Malthus's age has not yet run its full course in either the Third World or the OECD world. The Third World, which has reduced mortality rates more than twice as fast as the rich nations did, is still seeking to catch up to current OECD levels (Kelley 1988). However, even the rich nations do not appear to have exhausted the potential for rapid improvement. Studies of particularly long-lived subpopulations (Manton, Stallard and Tolley 1991) suggest that, within the present state of medical technology, such changes in lifestyle as the elimination of substance abuse (tobacco, alcohol, and narcotics), improved nutrition, and proper regimens of exercise can, by themselves (without new medical interventions), increase life expectation by 15 to 20 years. Since more global changes in environment and more far reaching medical interventions are not included in these estimates, it may well be that the twenty-first century will witness advances in life expectations, reductions in morbidity rates (this time from chronic diseases), and increases in labor productivity that rival those of the twentieth century.

We are on the verge of entering a post-Malthusian world in which, not natural resources, but only the rate of technological progress, the supply of key scientific and technical skills, the preference for goods and services over leisure, the prevalence of the egalitarian ethic, and the felicity of political systems will constrain human opportunity. How smooth the transition will be and how rapid the entry of the nations of the Third World will be depends, in no small measure, on the felicity of public policy in the OECD nations.

NOTES

1. The material in the first eight paragraphs draws on a previous paper. I have cited here only a few of the studies on which this compressed survey is based. For more complete documentation, readers should refer to Fogel 1991.

2. Although the English series published by Wrigley and Schofield extends back to 1541, the French series published by the Institut National d'Etudes Démographiques (INED) currently extends back only to 1740 (INED 1977; Wrigley and Schofield 1981). However, Rebaudo (1979) and Dupâquier (1989) have recently drawn together some samples which, though smaller than INED samples for the years after 1740, make it possible to compare England and France over the period 1675-1725.

3. From comments made at the Bellagio Conference on Hunger and History, June 1982.

4. The factor 1.27 is obtained on the assumption that 8 hours are spent at sleep or at least in bed at a factor of 1.0 BMR, and that essential minimal movements during waking hours have a factor of 1.4 BMR. Hence, over 24 hours the factor is $0.6667 \times 1.4 + 0.3333 \times 1.0 = 1.27$.

5. Although Toutain's estimate of the national food balance sheet for c.1785 may be too low by as much as 200 kcal per capita, the difference between food available for consumption at the household level and national food balance sheets is of the same order of magnitude due to distributional losses. Hence, use of Toutain's estimate for comparison with English estimates based on household purchases is acceptable. For a further discussion of this point see Fogel (1993b).

6. Among the major forces that might change the shape of Waaler surfaces over time are shifts in the cdr *per se* and changes in medical technology. Even a long-term shift in the cdr level, which might be mainly attributable to improved nutrition, in itself need not necessarily alter the Waaler surface (this needs to be further investigated), since the risk levels on a Waaler surface are measured relative to the cdr of the population.

   Changes in medical technology are more likely to alter the Waaler surface. For instance, if rapid advances were made in treatments of diseases associated with underweight people but little progress is made in diseases associated with obesity, the relative risk level would fall for low BMIs and rise for high BMIs, tilting the Waaler surface downward on the left. On Figure 4 in the paper, this would show up as a shift of all contour curves to the left, with the distance between contour curves widening in low-BMI regions and vice versa for high-BMI regions.

Changes in lifestyles and habits would also change the Waaler surface. A population that smokes would have a different surface than a non-smoking population (low BMIs would have higher risks in a smoking population).

I am indebted to John M. Kim for this footnote, which is based on work stemming from his dissertation, "Waaler Surfaces: A New Perspective on Height, Weight, Mortality, and Morbidity."

7. I include the aristocracy and other members of the governing classes in the nonagricultural sector even though their wealth was mainly in land since they were not engaged in farming.

8. Other assumed distributions of the meager supply of food to the nonagriculture sector yield some output. If the richest 30 percent seized all of the food, they could have produced about 100 million kcal of work. But then the other 70 percent of the nonagricultural population would have starved to death in weeks. See Fogel (1991) for further details, including a discussion of more likely adjustments, such as a drastic reduction in the size of the nonagricultural sector.

9. For recent restatements of the Malthusian theory that focuses on fertility see Schultz 1981 and Von Tunzelman 1986; cf. United Nations 1973, ch. 3. See Easterlin 1968 and 1980 on the baby-boom and cohort-size theories. The results of the European fertility project are summarized in Coale and Watkins 1986 The findings of the World Fertility Survey are reported in Cleland and Scott (1987). See Becker 1991 for an up-to-date statement of the theories of the new household economics and Goldin 1990 for an example of how these theories are applied empirically.

10. In this connection it is worth noting that the rise of the factory reduced the pressure on the food supply by reducing the amount of dietary energy required per hour of labor. This change was due partly to the fact that jobs in light manufacturing industry were less intensive in human energy than farming and partly to the substitution of waterpower and mineral energy for dietary energy.

11. I define premature mortality during the eighteenth century as the difference between the average crude death rate of that century and the English death rate of 1980 standardized for the English age structure of 1701-1705. The average premature mortality was 21.12 per thousand. Of that amount, 0.83 per thousand was due to crisis

mortality, 1.36 was due to the excess mortality of the persons in the next to lowest decile of the English caloric distribution (shown in Table 2, above), and 2.16 was due to the excess mortality of those in the lowest decile of the caloric distribution (Fogel 1992b, Table 9.1). Excess mortality in the two bottom deciles is defined as the difference between the mortality rates of persons of average stature and BMI in England c.1790 and the mortality rate of persons with the stature and BMI of persons in the two bottom deciles. The distributions of stature and BMI by caloric deciles are from Fogel and Floud 1994. The relative mortality rates by stature and BMI are from Fogel 1993b, Table A2).

12. It was assumed that the bottom 20 percent of the English consuming units were 157 centimeters tall, with a weight of about 47 kilograms, which implies a BMR of about 1,342 kilocalories and about 1,704 kilocalories for maintenance. The estimated average caloric intake of the second decile of the English caloric distribution in 18-IV was 1,903 kilocalories. Strolling requires about 76.56 kilocalories above maintenance, so that such an individual could stroll for about 2.6 hours. One hour of heavy manual labor, including rest breaks, requires 219 kilocalories above maintenance, and 335 kilocalories above maintenance while engaged. Computed from the requirements in FAO/WHO/UNU 1985, p.76.

13. Although it is my guess that these two influences tend to cancel each other out, it may be that the share of energy above maintenance allocated to work (measured GNP) is lower now than in the past. In that event the estimate of the share of British economic growth accounted for by improved nutrition and health would be overstated. The other implicit assumption is that the efficiency with which tall people convert energy into work output is the same as that of short people. An enormous literature has developed on this question but the evidence amassed so far is inconclusive. However, even if both of these assumptions tend to bias upward the share of British economic growth attributed to improved nutrition, it is quite unlikely that the bias could be as much as fifty percent. Hence it appears that improved nutrition and health accounted for at least 20 percent of British economic growth and the best estimate could be as high as 30 percent.

Of course, there are biases that run in the opposite direction. As Kim has pointed out, "Depending on how the caloric requirement for BMR and basic maintenance are defined and estimated, it is possible that the actual contribution of improved nutrition and health might be greater than the estimated 30 percent. Provided that changes in height and BMI affect not only mortality but also morbidity, shorter- and lower-BMI people will have a higher incidence of disease and illness, which would increase the caloric claims against diet, leaving less calories available for work and also leading to a higher number of sick days. If BMR and basic maintenance fail to take full account of such greater caloric demands by the higher incidence of diseases and illness in a shorter and lighter population, estimates of the effect of improved nutrition and health on economic growth will be biased downward.

"The shorter and lighter British population of 1790 would have had a higher incidence of disease and illness than the 1980 population, requiring that a greater (negative) adjustment be made to the estimated calories available for work. This leads to a higher estimate of the increase in calories available for work between 1790 and 1980 and hence the contribution of improved health and nutrition would be greater than the estimated 30 percent." From a memorandum by John M. Kim dated November 4, 1991.

14. There are, in addition, the vaccines, such as those for polio, rubella, and diphtheria, which have reduced the incidence of once common diseases and also their costly sequalia, and the antibiotics drugs that have proved so effective in fighting bacterial infections. To the extent that these drugs have reduced biomedical stress at early ages, they may have a significant impact on the reduction of chronic diseases later in the life cycle.

15. Nor can the decline in the participation rate be attributed to the decline in the share of farmers in the labor force, since the retirements rates of farmers were as high as those of nonfarmers (Costa 1993).

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