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THE CONQUEST OF HIGH MORTALITY AND HUNGER IN EUROPE AND AMERICA: TIMING AND MECHANISMS

Robert William Fogel

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ABSTRACT

The modern secular decline in mortality in Western Europe did not begin until the 1780s and the first wave of improvement was over by 1840. The elimination of famines and of crisis mortality played only a secondary role during the first wave of the decline and virtually none thereafter. Reductions in chronic malnutrition were much more important and may have accounted for most of the improvement in life expectation before 1875. Chronic malnutrition were much more important and may have accounted for most of the improvement in life expectation before 1875. Chronic malnutrition could not have been eliminated merely by more humane national policies, but required major advances in productive technology. Although there were some improvements in the health, nutritional status, and longevity of the lower classes in England and France between 1830 and the end of the nineteenth century, these advances were modest and unstable, and included some reversals. An even larger reversal occurred among the lower classes in the United States. Although the technological progress, industrialization, and urbanization of the nineteenth century laid the basis for a remarkable advance in health and nutritional status during the first half of the twentieth century their effects on the conditions of life of the lower classes were mixed at least until the 1870s or 1880s. The great gains of the lower classes were concentrated in the sixty-five years between 1890 and 1955. Improvement in nutrition and health may account for as much as 30 percent of the growth in coventionallly measured per capita income between 1790 and 1980 in Western Europe, but for a much smaller proportion in the United States.

Robert William Fogel
Graduate School of Business
University of Chicago
Chicago, Illinois 60637

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Recent findings in economic and demographic history as well as in the biomedical sciences have shed new light on the struggle to escape from high mortality and hunger in Western Europe and the United States. Although some of the investigations are still at an early stage, the outline of a new interpretation has begun to emerge. Attempts to predict now what the final picture will look like are necessarily risky. Nevertheless, I believe that it is useful to draw together various aspects of the recent findings in a way that indicates where we stand, what issues require further investigation, and to conjecture about how the pieces might ultimately fit together. Provided that due caution is exercised, such a provisional interpretation not only suggests the wider significance of what otherwise appear to be disjointed investigations, but also helps contribute to the social agenda for the next round of research.

I will present this provisional interpretation first as a set of theses and in the balance of the paper discuss several of them. The evidence suggesting these theses is drawn primarily, but not exclusively, from Great Britain, France and the United States.

Eleven Theses

Thesis 1: The modern secular decline in mortality in Western Europe did not begin until the 1780s and the first wave of improvement was over by 1830 in England and by 1840 in France.

Thesis 2: The elimination of crisis mortality played only a secondary role in the first wave of the secular decline in mortality, and virtually none thereafter. Over 90 percent of the initial decline was due to the reduction in "normal" mortality.

Thesis 3: The famines that plagued England and France between 1500 and 1800 were man-made, due to a failure of government policy rather than to natural calamities or inadequate technology, and could have been eliminated nearly two centuries before they were.

Thesis 4: The elimination of famines played only a minor role in the initial escape from high mortality, accounting at most for six percent of the initial decline.

Thesis 5: Although the elimination of famines played only a minor role in the first wave of the mortality decline, reductions in chronic malnutrition were much more important and may have accounted for most of the initial improvement.

Thesis 6: Chronic malnutrition, which was a major factor in the high mortality rates prevailing before 1780, could not have been eliminated merely by more humane national policies, but required major advances in productive technology.

Thesis 7: Although there were some improvements in the health, nutritional status, and longevity of the lower classes in England and France between 1830 and the end of the nineteenth century, these advances were modest and unstable, and included some reversals. An even larger reversal occurred among the lower classes in the United States.

Thesis 8: Although the technological progress, industrialization, and urbanization of the nineteenth century laid the basis for a remarkable advance in health and nutritional status during the first half of the twentieth century, their effects on the conditions of life of the lower classes were mixed at least until the 1870s or 1880s. In the U.S. the negative effects probably exceeded the positive ones through the 1870s, while in Western Europe the outcome of the conflicting factors was more even and may have been slightly positive.

Thesis 9: The great gains of the lower classes in nutritional status, health, and longevity began later and moved more swiftly in both Western Europe and the United States than is often presumed. Most of the gains were concentrated in the sixty-five years between 1890 and 1955.

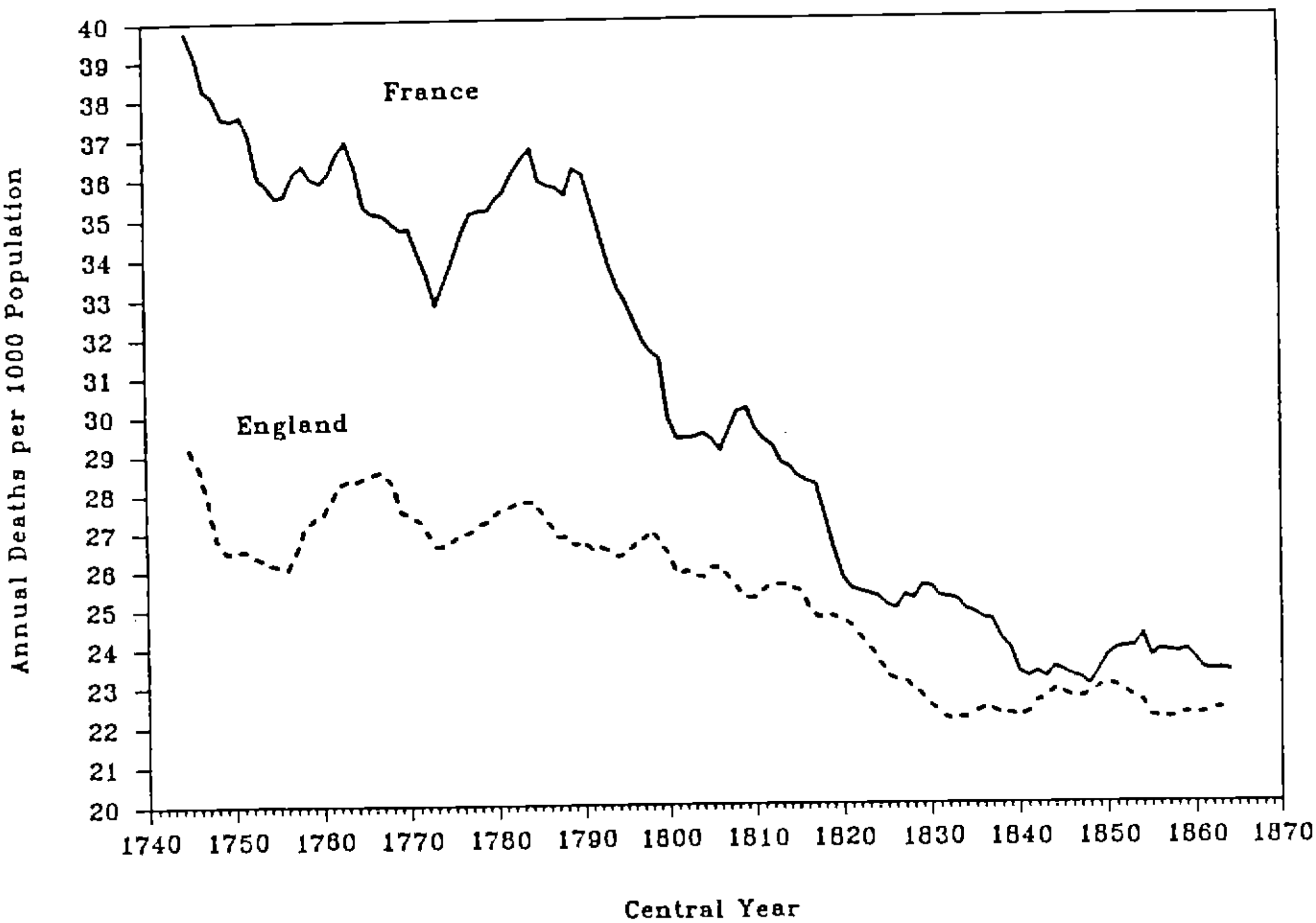
Thesis 10: The principal mechanisms for the escape from high mortality and poor health were the elimination of chronic malnutrition, the advances in public health, the improvement in housing, the reduced consumption of toxic substances, and the advances in medical technology. However, the relative importance of each of these factors in the escape is still a matter of controversy.

Thesis 11: Improvement in nutrition and health may account for as much as 30 percent of the growth in conventionally measured per capita income between 1790 and 1980 in Western Europe, but for a much smaller proportion in the United States.

Demographic Crises, Famines, and the Secular Decline in Mortality: Theses 1-4

The evidence on the timing of the secular decline in mortality (thesis one) comes mainly from Wrigley and Schofield (1981) and from Weir (1984) who in turn relied on data developed by INED (1977) for the period 1740- 1829. Both the English and French time series show that the crude death rates were high until 1780s, when the English series begins to decline (see Figure 1).[1] It bottoms at about 22 per 1000 and remains stable until the beginning of the 1870s. The French series begins to decline about half a decade later than the English, but proceeds at a much more rapid rate, reducing the original gap of

Figure 1
Crude Death Rates in France and England, 1740–1870.



Sources: See Note 1.

about 9 per 1000 to about 2 per 1000 by the late 1830s, after which the French death rate stabilizes at about 24 per 1000.

The evidence to support thesis 2 also comes from Wrigley and Schofield (1981) who, for the first time, had a sample of parishes large enough in number and wide enough in geographic scope to permit an estimate of the national impact of mortality crises on the annual crude death rate in early modern England. Over the 331 years in their study they found 45 crisis years, defined as a year in which the annual crude death rate (cdr) is more than 10 percent above a 25-year moving average of crude death rates. By combining the information from two of their tables it is possible to assess the impact of crisis mortality on the average crude death rate. The result of the computation is summarized in Table 1. Perhaps the most important aspect of their data is that it drastically diminishes the role of crisis mortality as an explanation for the high average mortality rates that prevailed before 1750. During the 210 years ending with that date, crisis mortality accounted for less than 6 percent of total mortality. When crisis mortality is expressed as a percentage, not of total contemporary mortality, but of "premature" mortality (the excess of the average cdr for the period less the English death rate in 1980), the figure rises to 13.2 percent.[2] An implication of Table 1 more directly relevant for thesis 2 is that just 6 percent of the decline in the annual crude death rate between the third quarter of the eighteenth century and the second quarter of the nineteenth century was due to the elimination of crisis mortality ($0.27 \div 4.70 = 0.057$).

Table 1 also has a bearing on thesis 4, since it follows that even if every mortality crisis identified by Wrigley and Schofield was due to famines, then the elimination of famines would, at most, account for 6 percent of the

Table 1
THE IMPACT OF CRISIS MORTALITY
ON THE AVERAGE CRUDE DEATH RATE,
1541-1871

Period	1	2	3	4	5
	Crude death rate per thousand person years	Crisis mortality per thousand person years	Crude death rate after factoring out crisis mortality (per thousand)	Crisis mortality as percentage of average mortality	Crisis mortality as percentage of "premature" mortality
1. 1541-1750	27.66	1.57	26.09	5.68	13.16
2. 1751-1775	27.28	0.40	26.88	1.47	1.97
3. 1776-1800	26.85	0.55	26.30	2.05	2.77
4. 1801-1825	25.40	0.15	25.25	0.59	0.82
5. 1826-1850	22.58	0.13	22.45	0.58	0.83
6. 1851-1871	22.42	0.13	22.29	0.58	0.84

Sources and methods of computation: See Fogel 1988a, pp. 6-7. "Premature" mortality is defined as the crude death rate of a given period minus the English death rate of 1980 standardized on the English age structure of 1701-1705.

first wave of the secular decline in mortality. However, as Wrigley, Schofield, and Lee have demonstrated, most crisis mortality was unrelated to subsistence crises (Wrigley and Schofield 1981, pp. 332-373; Lee 1981; Schofield 1983). Using procedures different from those that they followed, I have estimated that less than 10 percent of all crisis mortality during the 331 years that they covered was due to famines (Fogel 1986b, pp. 494-495; Fogel 1988a, appendix). These findings should not be taken to imply that there were not times when local famines produced large increases in local mortality rates. Too much evidence of local disasters induced by food shortages has accumulated to rule out such phenomena. However, in light of the evidence developed by Wrigley and Schofield, it now seems likely that dramatic as they were, the elimination of famines could not have accounted for as much as 6 percent of the decline in annual mortality between the third quarter of the eighteenth century (18-III) and the second quarter of the nineteenth century (19-II).

The evidence for thesis 3 has been developed in the course of efforts to assess the types of inferences that can be made validly about the supply of food from data on grain prices. Attempts to make such inferences date back beyond Gregory King, although he was the first to propose explicitly something approaching a demand curve -- the famous King's Law. After King, a host of political mathematicians and economists proposed variants of King's Law to predict the shortfalls in annual grain yields from the annual deviations of grain prices around their trend. In recent years this procedure was invoked by economic historians in France (Labrousse 1944) and Britain (Hoskins 1964, 1968) to identify subsistence crises. Hoskins used annual deviations from a 30-year moving average of wheat prices to identify subsistence crises, and concluded that there was a major wheat shortage once every 6 years between 1480 and 1759. He attributed the sequences of high prices that he found, not primarily to weather cycles but to the low (between 4 and 5) yield-to-seed ratio. Hoskins suggested that one bad harvest tended to generate another because starving farmers were forced to consume their reserve for seeds. Wrigley and Schofield used annual deviations from a 25-year moving average of an index of real wages (basically the inverse of an index of food prices) and found a pattern of subsistence crises quite similar to that of Hoskins, but little connection between subsistence and mortality crises.

The problem with this approach to the measurement of subsistence crises lies not in it logic but in the difficulty of estimating the price elasticity. If the elasticity of the demand for grain were known, the shortfall in the supply would follow directly from the deviation in price. Efforts to estimate that parameter from King's Law or variants of it (such as the formulas of Davenant, Jevons and Bouniatian) imply values of ϵ in the neighborhood of 0.4 (Wrigley 1987; Fogel 1988a). The difficulty with these estimates is that they are based on the implicit assumption that the annual supply of grains varied directly with the annual per acre yield. That assumption would be correct only if carryover inventories at the beginning of the harvest were zero. Yet carryover inventories ran between four and five months of annual consumption. When King's Law is reestimated allowing for the effect of these stocks, the value of ϵ declines from 0.4 to 0.25. Additional evidence bearing on the exceedingly inelastic demand for inventories by those who held them, indicates that the best estimate of ϵ is in the neighborhood of 0.18 (Fogel 1988a).

A price elasticity of 0.18 implies that even relatively small declines in supply would lead to sharp rises in prices. Moreover, because of large differences in the elasticity of demand for grain between the upper and lower classes, a reduction in the supply of grain by as little as 5 percent would set off a spiral rise in prices that cut the consumption of the laboring classes by a third (Fogel 1988a). Thus the typical subsistence crises took place not because there was not enough grain to go around, but because the demand for inventories pushed prices so high that laborers lacked the cash to purchase the grain. Even in the largest deviation of wheat prices above trend during Hoskins's entire 280-year period or Wrigley and Schofield's 331-year period involved a manageable shortfall in the supply of food. Although carryover stocks were diminished, more than two- thirds the normal amount -- more than a three months supply -- remained over and above all claims for seed, feed, and human consumption.

During the Tudor era authorities recognized that famines were man- made rather than natural disasters because the available surpluses were more than adequate to feed the lower classes. The basic strategy of the Crown was to leave the grain market to its own devices during times of plenty. But in years of famine for the lower classes, the state became increasingly bold in overriding the complaints of traders, merchants, brewers, bakers, and other processors about its meddling in the market. Since mere denunciations of engrossers did not work, in 1587 the Privy Council issued a "Book of Orders" which instructed local magistrates to determine the extent of private inventories of grain and to force their owners to supply grain to artificers and laborers at low prices. Although it took more than a decade to overcome local resistance to these orders, by 1600 local authorities were vigorously responding to the directives of the Crown. Historians are generally agreed about the diligence of the authorities during the reigns of James I and

Charles I, but not over whether their paternalistic policies actually worked. In any case, the paternalistic system began to unravel with the Civil War. Since the heavy-handed intervention of the Crown in grain markets was one of the grievances of the opposition to Charles, Parliament developed a legislative program aimed at unshackling farmers, producers, and merchants from the restraints that had been imposed on them. Some scholars view the new grain policies as acts of self-aggrandisement by the landlords, traders, and merchants who controlled Parliament, while others argue that the new policies were aimed at stimulating a depressed agriculture, improving marketing and transportation, and promoting industry (Leonard 1965, Lipson 1971, Jordan 1959, Supple 1964, Barnes 1930, Rose 1961, Everitt 1967, Thirsk 1985a and b, Chartres 1985).

Whatever the motivation for the switch in policy, it was the abandonment of the Tudor-Stuart program of food relief, not natural disasters or the technological backwardness of agriculture, that subjected England to periodic famines for two extra centuries. Analysis of variance indicates that during the period from 1600 to 1640, when government relief efforts were at their apogee, the variance of wheat prices around trend declined to less than a third of the level of the preceding era. That large a drop cannot be explained plausibly by chance variations in weather, since the F-value is statistically significant at the 0.0001 level. Nor is it likely that the sharp rise in the variance of wheat prices during the last six decades of the seventeenth century was the result of chance variations in weather (Fogel 1988a).[3]

In the absence of government action to reduce prices during grain shortages, workers took to the streets and price-fixing riots became a standard feature of the eighteenth century. During the early decades of the eighteenth century the government sought to cope with such outbreaks by enforcing vagrancy and settlement laws and by force (Lipson 1971, III, pp. 457-467; Rose 1961). During the late 1750s, however, after food riots of unprecedented scope and intensity, proposals reemerged for the government to intervene vigorously in the grain market (to return to the Tudor-Stuart policies), including proposals to reestablish public granaries. As the battle over these questions ebbed and flowed during the next half century, the government, at the local and the national levels, gradually shifted toward more vigorous intervention in the grain market. However, it was not until the nineteenth century that the government control over stocks became adequate to reduce the variance in wheat prices to the level that prevailed at the apogee of Tudor-Stuart paternalism. By the middle of the nineteenth century, famines had been conquered, not because the weather had shifted, or because of improvements in technology, but because government policy (at least with respect to its own people)[4] had unalterably shifted back to the ideas and practices of commonweal that had prevailed during 1600-1640 (Barnes 1930, pp. 31-45; Post 1977).

The Extent and Significance of Chronic Malnutrition: Theses 5 and 6

Although the possibility that famines might have had only a small impact on aggregate mortality had been anticipated (Lebrun 1971; Flinn 1974; Flinn 1981), Wrigley and Schofield provided the data needed to measure the national impact. By demonstrating that famines and famine mortality are a secondary issue in the escape from the high aggregate mortality of the early modern era, they 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 malnutrition might be related to the trend in mortality and how to identify the factors that determined each of these secular trends.

The new problems require new data and new analytical procedures. In this connection one must come to grips with the thorny issue of the distinction between diet (which represents gross nutrition) and nutritional status (which represents net nutrition: the nutrients available to sustain physical development). I will not dwell on this distinction here (see Fogel 1986b) but will only emphasize that when I mean gross nutrition I will use the term diet, and that such other terms as "malnutrition," "undernutrition," "net nutrition," and "nutritional status" are meant to designate the balance between the nutrient intake (diet) and the claims on that intake.

Malnutrition can be caused either by an inadequate diet or by claims on that diet (including work and disease) so great as to produce widespread malnutrition despite a nutrient intake that in other circumstances might be deemed adequate. There can be little doubt that the high disease rates prevalent during the early modern era would have caused malnutrition even with extraordinary diets, that is with diets high in calories, proteins and most other critical nutrients. I believe that the United States during 1820-1880 is a case in point, and I will return to that example later. However, recent research indicates that for many European nations prior to the middle of the nineteenth century, the national production of food was at such low levels that the lower classes were bound to have been malnourished under any conceivable circumstance, and that the high disease rates of the period were not merely a cause of malnutrition but undoubtedly, to a considerable degree, a consequence of exceedingly poor diets.

Recently developed biomedical techniques, when integrated with several standard economic techniques, make it possible to probe deeply into the extent and the demographic consequences of chronic malnutrition during the eighteenth and nineteenth centuries. The biomedical techniques include improved approaches to the estimation of survival levels of caloric consumption and of the caloric requirements of various types of labor; epidemiological studies of the connection between stature and the risk of both mortality and chronic diseases; and epidemiological studies of the connection between body mass indexes (BMI) and the risk of mortality. The economic techniques include various methods of characterizing size distributions of income and of calories, as well as methods of relating measures of nutrition to measures of income and productivity.

Energy Cost Accounting: The Cases of Britain and France During the Last Quarter of the Eighteenth Century

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 age 20-39 living in moderate climates, BMR normally ranges between 1,350 and 2,000 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). Since 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. 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 beyond 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. For a typical well- fed adult male engaged in heavy work, BMR and maintenance require about 60 percent of energy consumption, work 39 percent, and discretionary activity just one percent. For a well-fed adult male engaged in sedentary work (such as an office clerk), a typical distribution would be: BMR and maintenance 83 percent, work 5 percent, discretionary activity 13 percent. For a 25-year old adult male engaged in subsistence farming in contemporary Asia, a typical distribution would be: BMR and maintenance 71 percent, work 21 percent, and discretionary activity 8 percent. Similar distributions of energy requirements have been developed for women as well as for children and adolescents of both sexes. In addition, 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 2 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).

Historical estimates of mean caloric consumption per capita have been derived from several principal sources: national food balance sheets; household consumption surveys; food allotments in hospitals, poor houses, prisons, the armed forces and other lower class institutions; food entitlements to widows in wills; and food allotments in noble households, abbeys and similar wealthy institutions. National food balance sheets estimate the national supply of food by subtracting from the national annual production of each crop, allowances for seed and feed, losses in processing, changes in inventories, and net exports (positive or negative) to obtain a residual of grains and vegetables available for consumption. In the case of meats the estimates begin with the stock of livestock, which is turned into an annual flow of meat by using estimates of the annual slaughter ratio and live weight of each type of livestock. To estimate the meat available for consumption it is necessary to estimate the ratio of dressed to live or carcass weight, as well as the distribution of dressed weight among lean meat, fat, and bones (Fogel and Engerman 1990 and 1974, II, pp. 91-99).

Household surveys are based upon interviews with families who are asked to recall their diets for a period as short as one day (the previous day) or their average diet over a period of a week, a month, a year, or an undefined

Table 2
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	(i.e. 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	
Ploughing	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	-	

Note: Sources are FAO/WHO 1985, 76-78, 186-191; Durnin and Passmore 1967, 31,66,67,72. 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 women of average build (31).

period designated by their "normal diet". In recent times, such surveys may be based on a daily record of the food consumed, which is kept either by a member of the family or by a professional investigator. Institutional food allowances are based on food allotments for each class of individuals layed down as a guide for provisions purchased by the institution (as in the case of victualling allowances for military organizations and daily diet schedules adopted in abbeys, noble households, schools, workhouses, hospitals, and prisons) as well as descriptions of meals actually served and actual purchases of food for given numbers of individuals over particular time periods (Oddy 1970; Appleby 1979; Morell 1983; Dyer 1983). Food entitlements of widows and aged parents were specified in wills and contracts for maintenance between parents and children or other heirs (in anticipation of the surrender of a customary holding to an heir). Such food entitlements have been analyzed for England, France, the United States and other countries at intermittent dates between the thirteenth century and the present (Bernard 1975; Dyer 1983; McMahon 1981; for studies of other countries see Hémardinquer 1970).

Although these sources of information on the average consumption of nutrients contain valuable information, they are also fraught with difficulties. In the case of the national food balance sheets, for example, the accuracy of the estimates depends in the first instance on the accuracy of the production figures and on the various coefficients used to transform outputs of grains and stocks of animals into food available for human consumption. However, even if the outputs and factors used to produce the national food supply are accurate, the average amount of nutrients produced is not necessarily equal to the average amount consumed. Not only are there storage and food processing losses before the supply reaches the household, but within the household as well. There is also the question of the amount of food put on an individual's plate that is not consumed (plate waste and feeding to pets).

Household food surveys, especially those of past times, have their own set of problems. They are focused largely on lower-class diets and are generally judgement samples. Hence it is difficult to know precisely where they are located in the national distributions of calories and other nutrients. Since these surveys sometimes include information on the income of households, it is possible to relate the average consumption of diets to the average income (or expenditures) of households. Such studies for English budgets generally indicate an income elasticity of the demand for food between the 1780s and the mid 1850s that is at the high end of those found for less developed nations today, which is not inconsistent with estimates of English per capita income for that period. However scholars are in disagreement over whether these households were below or above the middle of the English income distribution for their period or whether the reported income understates or overstates the true household income. Although, information on the size distribution of income before World War I is sparse, that which is available can be used to locate households in nutrient distributions (Crafts 1981; Woodward 1981; Shammas 1983; Shammas 1984).

Sources of information about food allotments in institutions and of food entitlements in wills often suffer from a common problem: lack of information on the age and sex of the recipients. Caloric requirements vary so significantly by age and sex that failure to standardize for these characteristics may cause misleading interpretations of the adequacy of diets, and shifts in the age-sex structure over time may bias the estimated trends in nutrition. Food wasting varied greatly by institutions so that the proportion of the food supply actually consumed was much lower in noble households than in poor households. No one, for example, could have consumed regularly the daily allowance at the royal households in Sweden of foods containing 6,400 calories (Heckscher 1954, pp. 21-22, 68-70). Even allowing for heavy work and cold climate, a third to a half of the allowance must have been wasted in storage, in preparation, and on the plate.

Toutain (1971), on the basis of a national food balance sheet, has estimated that the per capita consumption of calories in France was 1,753 during 1781-1790 and 1,846 during 1803-1812. Converted into calories per consuming unit (equivalent adult male), the figures become about 2,290 and 2,410 calories. Data in the household budget studies recently re-examined by economic historians indicate that English daily consumption during 1785-1795 averaged about 2,700 calories per consuming unit (Fogel 1988b; cf. Shammas 1984).

One way of assessing these two estimates is by considering their distributional implications. As has been noted elsewhere, all of the known distributions of the average daily consumption of calories for populations are not only reasonably well described by the lognormal distribution but have coefficients of variation that lie between 0.2 and 0.4 -- a narrow range that is determined at the top end by the human capacity to use energy and the distribution of body builds, and at the bottom end by the requirement for basal metabolism and the prevailing death rate (Fogel 1988b). Consideration of available evidence on mortality rates (Bougeois- Pichat 1965; Weir 1984) and the findings of Goubert (1960, 1973), Bernard (1969), Hufton (1974), Kaplan (1976), and others on the condition of the lower classes in France during the late ancien régime rule out either 0.2 or 0.4 as plausible estimates of the coefficient of variation and suggest that 0.3 is the best approximation in the light of current knowledge.[5]

Table 3 displays the caloric distribution for England and France implied by the available evidence. Several points about these distributions that lend support to Toutain's estimate for the French and the estimates derived for the English from the budget studies are worth noting. First, the average levels are not out of keeping with recent experiences in the less developed nations. Low as it is, Toutain's estimate of French supply of calories is above the average supply of calories in 1965 estimated for such nations as Pakistan, Rwanda, and Algeria, and only slightly less (39 calories) than that of Indonesia. The English estimate is above that for 30 less developed nations in 1965, including China, Bolivia, the Philippines, and Honduras, and only slightly below (37 calories) India (World Bank 1987).

Second, the distributional implications of the two estimates are consistent with both qualitative and quantitative descriptions of the diets of various social classes (Hufton 1974, 1983; Goubert 1973; L. Tilly 1971; C. Tilly 1975; Frijhoff and Julia 1979; Blum 1978; Cole and Postgate 1938; Rose 1971; Drummand and Wilbraham 1958; Pullar 1970; Wilson 1973; Burnett 1979; Mennell 1985). For example, Bernard's study (1975) of marriage contracts made in the Gévaudan during the third quarter of the eighteenth century revealed that the average ration provided in complete pensions was about 1,674 calories. Since the average age of a male parent at the marriage of his first surviving child was about 59, the preceeding figure implies a diet of about 2,146 calories per consuming unit (Fogel 1988b). That figure falls at the

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 France c. 1785 $\bar{X}$ = 2,290 (s/$\bar{X}$) = 0.3		B 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 1988b, esp. tables 4 and 5 and note 6.

47th centile of the estimated French distribution (Table 3, distribution A), which is quite consistent with the class of peasants described by Bernard.

The two estimates are also consistent with the death rates of each nation. The crude death rate in France c. 1785 was about 36.1 per thousand while the figure for England c. 1790 was about 26.7 (Weir 1984; Wrigley and Schofield 1981). It is plausible that much of the difference was due to the larger proportion of French than English who were literally starving (Scrimshaw 1987). The French distribution of calories implies that 2.48 percent of the population had caloric consumption below basal metabolism, most of them presumably concentrated at very young and at old ages. Table 5 implies that proportion of the English below basal metabolism was 0.66 percent. If a quarter of these starving individuals died each year (cf. Chen et al. 1981), they would account for about a fifth (6.6 per 1000) of the French crude death rate, but only about a sixteenth of the English rate (1.7 per 1000) and for about half of the gap between the crude death rates of the two nations.[6]

What, then, are the principal provisional findings about caloric consumption at the end of the eighteenth century in France and England? One is the exceedingly low level of food production, especially in France, at the start of the Industrial Revolution. Another is the exceeding low level of work capacity permitted by the food supply, even after allowing for the reduced requirements for maintenance because of small stature and reduced body mass (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.[7]

That English ultra poor were better off than the French ultra poor was partly due to the greater productivity of English agriculture (as measured by the per capita production of calories). However, the distribution of income was so unequal in England, that had it not been for the English system of poor relief, the proportion of the English that starved would have been nearly as great as that of the French. In response to the bread riots of the eighteenth century, English authorities substantially expanded the system of poor relief. Between 1750 and 1801, poor relief increased at a real rate of 2.3 percent per annum, which was nearly three times as fast as the growth of either G.N.P. or the pauper class (Crafts 1985, p. 45; M. Rose 1971, pp. 40-41; Marshall 1968, p. 26; Mitchell and Deane 1962, p. 469). Consequently, by c. 1790 relief payments to the ultra poor had become substantial, more than doubling the income of households in the lowest decile of the English income distribution. In pre-revolutionary France, on the other hand, the average annual relief provided to the ultra poor could purchase daily only about one ounce of bread per person (Fogel 1988b, n. 17 and 18). The responsiveness of the British government to the bread riots of the poor (Barnes 1930; R. Rose 1961; Marshall 1968), not only kept the English death rate from soaring but may have spared Britain from a revolution of the French type.

The Implications of Stature and Body Mass Indexes for the Explanation of Secular Trends in Morbidity and Mortality

The available data on stature and on body mass tend to confirm the basic results of the analysis based on energy cost accounting: chronic malnutrition was widespread in Europe during the eighteenth and nineteenth centuries. Recent advances in biomedical knowledge make it possible to use anthropometric data for the eighteenth and nineteenth centuries to study secular trends in European nutrition, health, and risks of 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. Until recently most of the studies have focused on children under 5, using one or more of the anthropometric indicators at these ages to assess risks of morbidity and mortality in early childhood and it was at these ages that the relevance of anthropometric measures was established most firmly (Sommer and Lowenstein 1975; Chen, Chowdhury, and Huffman 1980; Billewicz and McGregor 1982; Kielmann et al. 1983; Martorell 1985). During the last few years, however, a considerable body of evidence has accumulated suggesting that height at maturity is also an important predictor of the probability of dying and of developing chronic diseases at middle and late ages (Marmot, Shipley, and Rose 1984; Waaler 1984; Fogel et al. 1986). Body mass indexes have similar predictive properties (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. 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."

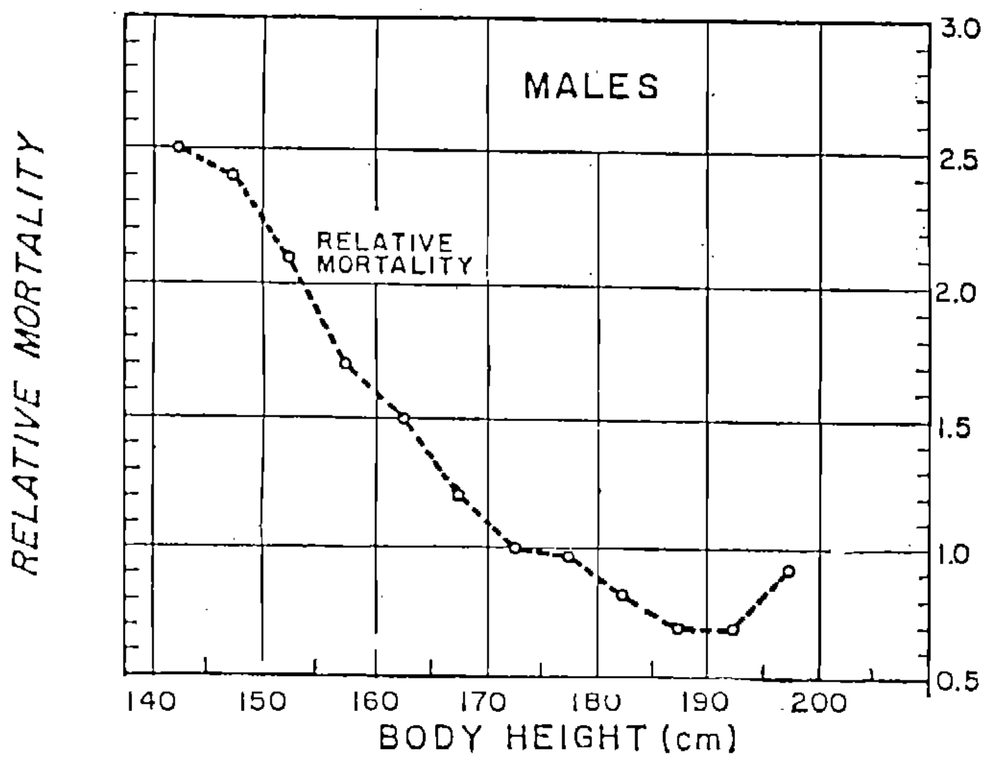
The predictive power of height and body mass indexes with respect to morbidity and mortality are indicated by Figures 2 and 3. Part A of Figure 2, reproduces a diagram by Waaler (1984). It shows that short Norwegian men aged 40-59 at risk between 1963 and 1979 were much more likely to die than tall men. 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. Both the Norwegian curve and the U.S. all-causes curve have relative risks that reach a minimum of between 0.6 and 0.7 at a height of about 187.5 cm. Both reach a relative risk of about 2 at about 152.5 cm. The similarity of the two risk curves in Figure 2, despite the differences in conditions and attendant circumstances, suggests that the relative risk of morbidity and mortality depends not on the deviation

FIGURE 2

A COMPARISON OF THE RELATIONSHIP BETWEEN BODY HEIGHT AND RELATIVE RISK IN TWO POPULATIONS

PART A

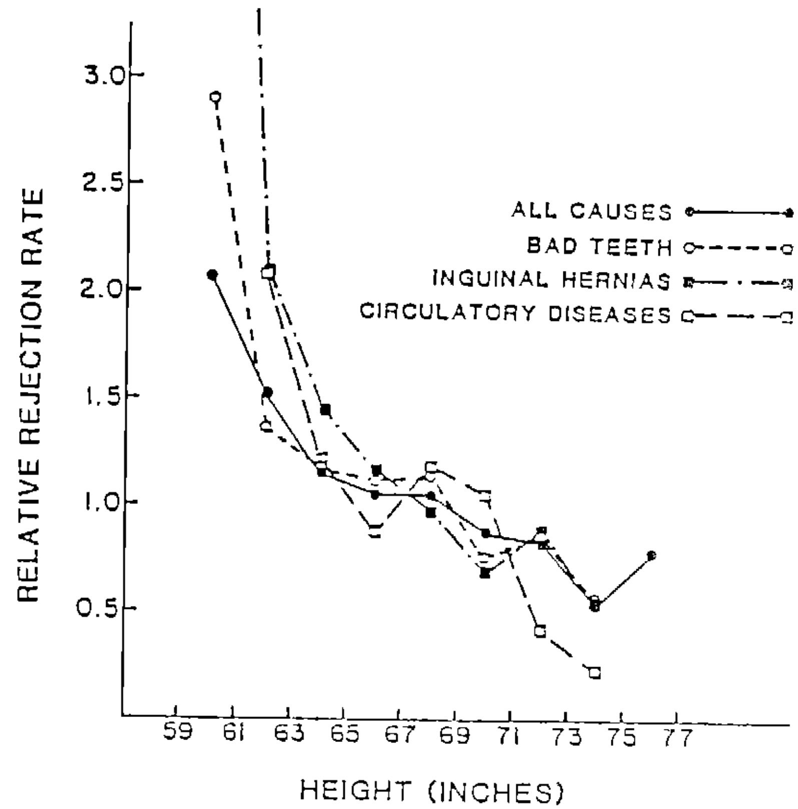
Relative mortality rates among Norwegian men aged 40-59, between 1963 and 1979



SOURCE: WAALER 1984

PART B

Relative rejection rates for chronic conditions in a sample of 4245 men aged 23-49 examined for the Union Army

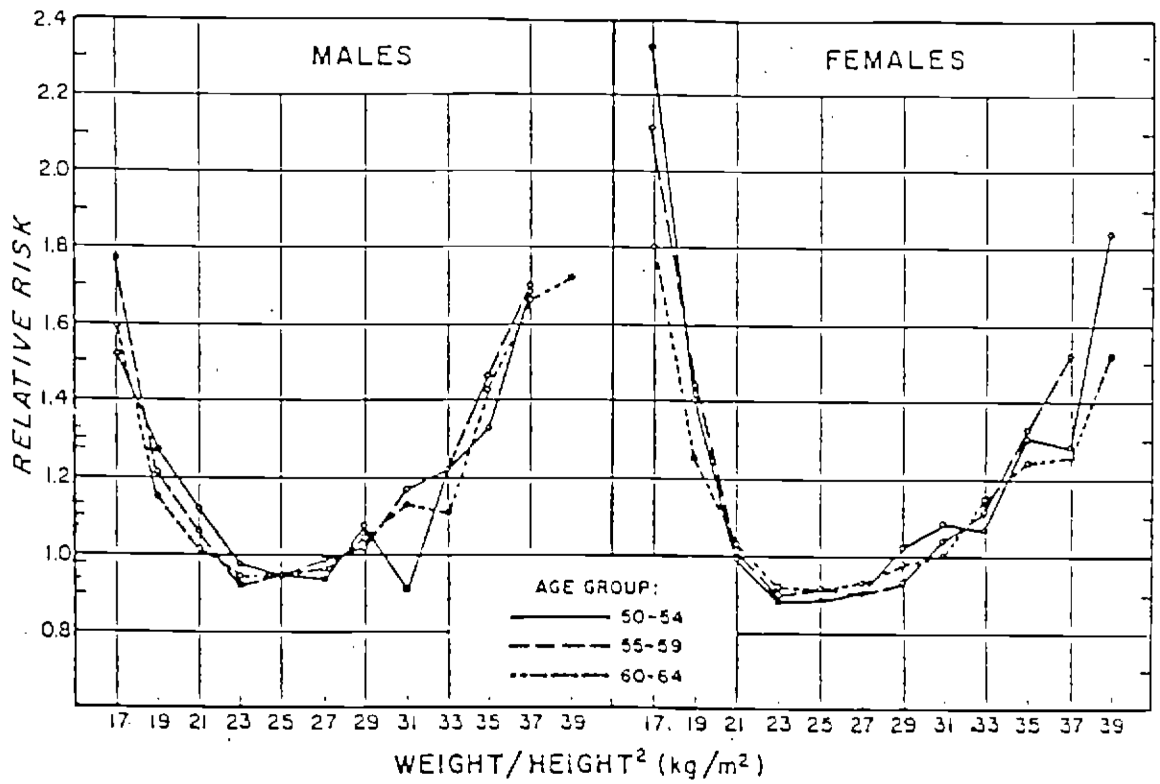


SOURCE: FOGEL ET AL., 1986

FIGURE 3

THE RELATIONSHIP BETWEEN BMI AND PROSPECTIVE RISK AMONG

NORWEGIAN ADULTS AGED 50-64 AT RISK BETWEEN 1963 & 1979



SOURCE: Waaler 1984

of height from the current mean, but from an ideal mean: the mean associated with full genetic potential.[8]

Waaler (1984) has also studied the relationship in Norway between a BMI and the risk of death in a sample of 1.8 million individuals. Curves summarizing his findings are shown in Figure 3 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 BMI's within the range 20-29. Within the range 20-29, the curve is relatively flat, with the relative risk of mortality hovering close to 1.0. However, at BMI's of less than 20 and over 29, the risk of death rises quite sharply as the BMI moves away from its mean value.[9] It will be noticed that the BMI curves are much more symmetrical than the height curves in Figure 2, which indicates that high BMI's are as risky as low ones.

Not only do adult height and the BMI measure different aspects of nutritional status, but their correlation in cross sections is relatively low, both within populations and over them (Benn 1971; Billewicz, Kemsley, and Thomson 1962; Waaler 1984; Fogel et al. 1986). The absence of such a correlation is explained by two important aspects of the biology of nutrition. 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; 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 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 confines 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).

The fact that a stunted individual is in energy balance at a good BMI does not imply that he or she is not at greater risk than a person not stunted, but only that the demands on their energy intake leaves them in energy balance at a satisfactory level -- without causing them to consume tissue in order to sustain their energy output. As Figure 4 shows (see p. 33), there is an optimum weight for a 160 cm male, a weight which makes his relative mortality risk a minimum. At a weight of 66 kg (BMI = 25.8), the risk of a 160 cm man is about 29 percent less than that of a similarly stunted male of just 51 kg (BMI = 19.9). On the other hand, even at his optimum weight, a 160 cm male is at about 55 percent greater risk than a 180 cm male of optimum mass (79 kg and BMI = 24.4).

What implications do these new analytical tools have for the interpretation of secular trends in nutritional status and mortality? Table 4

Table 4
Estimated Average Final Heights of Men Who Reached Maturity
Between 1750 and 1875 in Six European Populations,
by Quarter Centuries
(cm)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Date of maturity by century and quarter	Great Britain	Norway	Sweden	France	Denmark	Hungary
1. 18-III	165.9	163.9	168.1	--	--	168.7
2. 18-IV	167.9	--	166.7	160.5	165.7	165.8
3. 19-I	168.0	--	166.7	165.1	165.4	163.9
4. 19-II	171.6	--	168.0	166.7	166.8	164.2
5. 19-III	169.3	168.6	169.5	166.4	165.3	--
6. 20-III	175.0	178.3	177.6	172.0	176.0	170.9

Sources: Fogel 1988b, Table 7.

compares the final heights of seven populations for which final heights have been estimated during the period 1750-1875. They are all severely stunted by modern standards (see line 6 of Table 4). The French cohort of 18-IV is the most stunted, measuring only 160.5 cm (63.2 inches). The two next shortest cohorts are those of Norway for 18-III and Hungary for 18-IV, which measured 163.9 cm (64.5 inches). Britain and Sweden were the tallest populations between 1775 and 1875, although by the end of the period, Norway nearly matched the leaders.

France may have experienced the most rapid early growth rate of any nation shown in Table 4, with stature increasing by 1.24 cm per decade between 18-IV and 19-II. However, French heights declined slightly over the next quarter century and hovered between 165.3 and 166.7 until the turn of the twentieth century (Floud 1983a). British heights also increased quite rapidly (0.76 cm per decade) and for a longer period than the French. The increase over the first 75 years (18-III to 19-II) was 5.7 cm, more than three-fifths of the total increase in British heights between 18-III and the current generation of adults. However, British heights like those of the French, declined slightly with the cohort of 19-III and also remained on a plateau for about half a century (Floud, Gregory, and Wachter 1988). Swedish heights appear to have declined during the last half of the eighteenth century but then rose sharply beginning with the second quarter of the nineteenth century, initiating the marked secular increases in Swedish heights that have continued down to the present day.

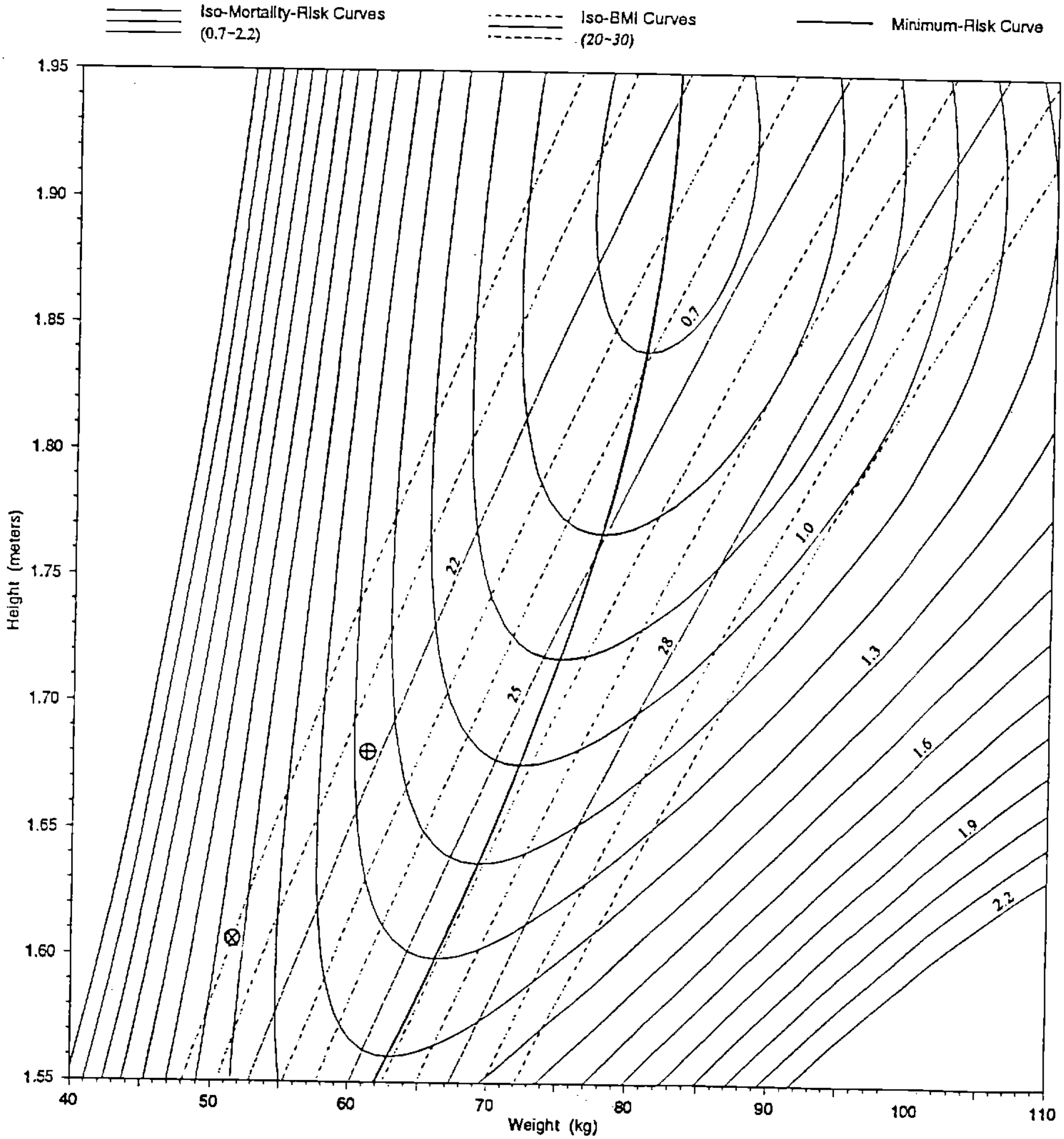
Indeed over the last century the three Scandinavian countries (shown in Table 4) and the Netherlands (Chamla 1983) have had the most vigorous and sustained increases in stature in the Western World, outpacing Britain and the

United States (Fogel 1986b). Hungary's growth pattern differs from that of all the other European nations. Its cohort of 18-III was taller than that of Sweden, but then Hungarian heights declined sharply for half a century and, despite a turnabout in the nineteenth century, remains one of the shortest populations in Europe. Its mean height today is below the level achieved by the British cohort of 19-II.

Data on body mass indexes for France and Great Britain during the late eighteenth and most of the nineteenth centuries are much more patchy than those on stature. Consequently attempts to compare British and French BMIs during this period are necessarily conjectural. It appears that c. 1790 the average English BMI for males about age 30 was between 21 and 22, which is about 10 percent below current levels. The corresponding figure for French males c. 1785 may only have been about 20, which is about 20 percent below current levels (Fogel 1988b). The conjectural nature of these figures makes the attempt to go from the anthropometric data to differential mortality rates more illustrative than substantive. However, Figure 4 indicates the apparent location of French and English males of 18-IV on the iso-mortality map generated from Waaler's data. These points imply that the French mortality rate should have been about 35 percent higher than that of the English, which is quite close to the relative mortality rates indicated by Figure 1.[10] In other words, the available data suggest that in 18-IV both France and Great Britain were characterized by the same mortality risk surface (i.e. the same mortality regimen) and that differences in their average mortality rates are explained largely by differences in their distributions of height and weight-for-height.

Figure 4

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



Note: ⊕ - the possible location of adult Englishmales aged 25~34 c. 1785 on the iso-mortality map.
⊗ - the possible location of comparable French males c. 1790.
All risks are measured relative to the average risk of mortality (calculated over all heights and weights) among Norwegian males aged 50~64.

This result raises the question as to how much of the decline in European mortality rate since 18-IV can be explained merely by increases in stature and BMIs, that is, merely by movements along an unchanging mortality risk surface. For the three countries for which even patchy data are available -- England, France, and Sweden -- it appears that nearly all of the decline in mortality between 18-IV and 19-III was due to movements along the Waaler mortality surface, since the estimated changes in height and BMI appear to explain virtually the entire decline in mortality during this three-quarters of a century. However, movements along the Waaler surface appear to explain only about 50 to 60 percent of the decline in mortality rates after 1875. After 1875 increases in longevity involved factors other than those that exercise their influence through stature and body mass. In other words, there were substantial shifts in the Waaler surface between 19-III and 20-III (Fogel 1988b).

The Instability of Improvements in Health and Nutritional Status for the Lower Classes Before the Twentieth Century and the Remarkable Achievements During the Twentieth Century: Theses 7, 8, and 9

Although the period from the middle of the eighteenth century to the end of the nineteenth has been hailed justly as an industrial revolution, a great transformation in social organization, and as a revolution in science, these great advances brought only modest and uneven improvements in the health, nutritional status, and longevity of the lower classes before 1890. It was not until well into the twentieth century that ordinary people in Europe and America began to enjoy regularly the levels of nutrition and longevity that characterize our age. Whatever contribution the technological and scientific advances of the eighteenth and nineteenth centuries may have made ultimately to this breakthrough, escape from hunger and high mortality did not become a reality for most ordinary people until the twentieth century.

Figure 5 summarizes the available data on U.S. secular trends in both stature and mortality since 1720. The time series of final heights shown in the upper portion of the figure are for native-born white males and are given as averages for five-year birth cohorts. The time series in stature is controlled for shifts in the distribution of the region of birth, of occupation, and of several other characteristics while the life expectancy series is not, but merely gives the mean life expectancy at age 10 of all of the individuals at risk during each period in the sample from which it was constructed. Since southerners were deficient in the sample of life spans an attempt to correct for this deficiency is shown by the line with short dashes. A line indicating the trend in life expectancy in Maryland during the eighteenth century is also displayed.

Both the series on stature and e_{10}^{0} on contain striking cycles. Both series rise during most of the eighteenth century, attaining both substantially greater heights and life expectations than prevailed in England during the same period (Floud 1985). Life expectancy began to decline during the 1790s and continued to do so for about half a century. There may have been a slight decline in the heights of cohorts born between 1785 and 1820, but the sharp decline, which probably lasted about half a century, began with cohorts born around 1830. A new rise in heights, the one with which we have long been familiar, probably began with cohorts born during the last decade of the nineteenth century and continued for about 60 years.

Data on final heights in America are not available for cohorts born before 1710, but the relatively flat profile between around 1710 and around

1750 and the tall stature compared with the English in 1750 suggests that heights were probably rising rapidly for several decades before our series begins. This inference is supported by data on food consumption in Massachusetts discovered by McMahon (1981). Wills deposited in Middlesex county between 1654 and 1830 indicate a sharp rise in the average amount of meat annually allotted to widows for their consumption. Between 1675 and 1750 the average allotment increased from approximately 80 to approximately 168 pounds per annum: about half the increase took place by 1710. The evidence both on stature and on food allotments suggests that Americans achieved an average level of meat consumption by the middle of the eighteenth century that was not achieved in Europe until well into the twentieth century (McMahon 1981; Holmes 1907; Fogel 1986).

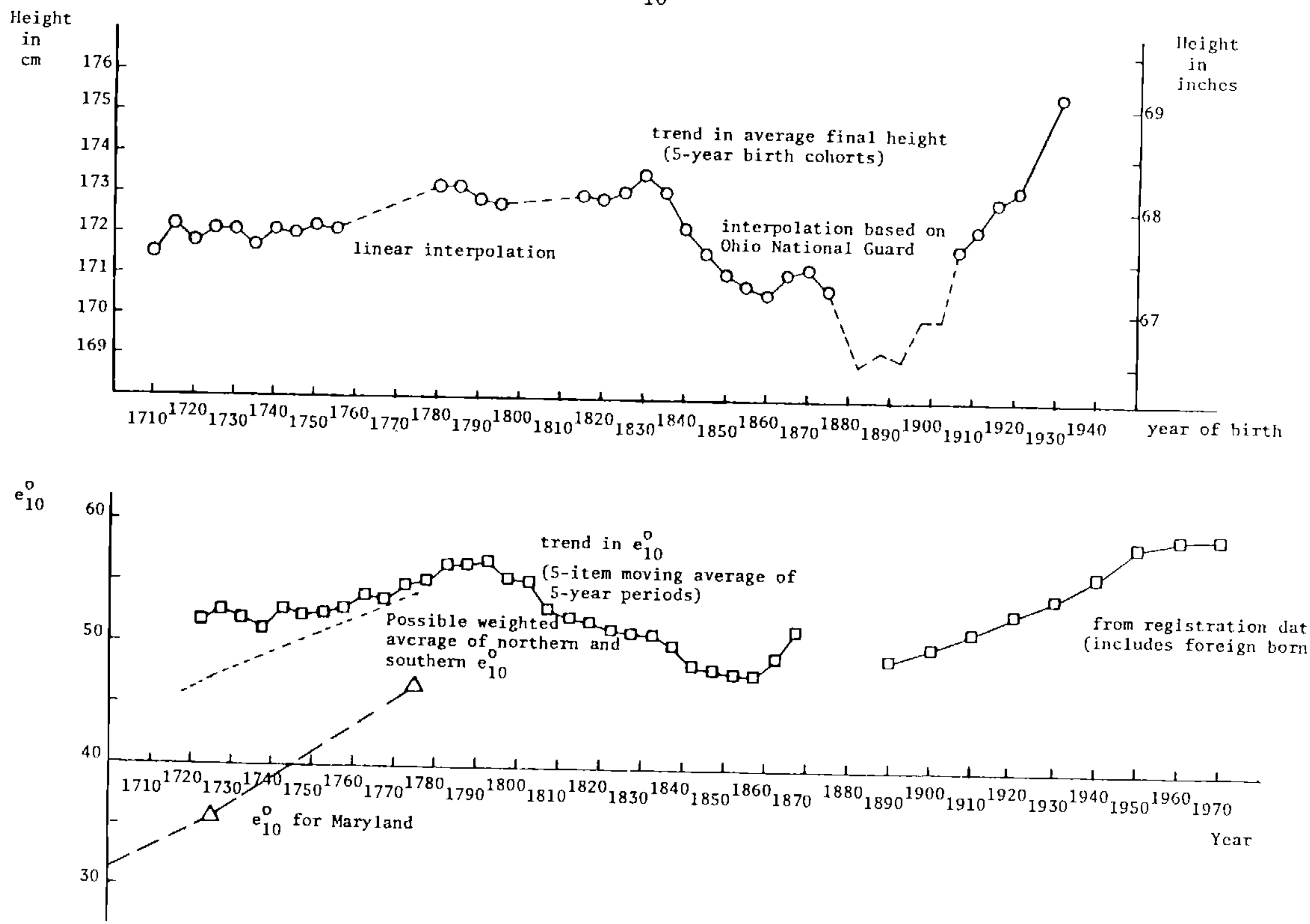
Figure 5 reveals not only that Americans achieved modern heights by the middle of the eighteenth century, but that they reached levels of life expectancy that were not attained by the general population of England or even by the British peerage until the first quarter of the twentieth century (Fogel 1986b, p. 467). The early attainment of modern stature and relatively long life expectancy is surprising. Yet in light of the evidence that has accumulated in recent years it is by no means unreasonable. By the second quarter of the eighteenth century, Americans had achieved diets that were remarkably nutritious by European standards, and particularly rich in protein. The American population was low in density, probably below the threshold needed to sustain major epidemics of such diseases as smallpox. The low density probably also reduced exposure to the crowd diseases of the nineteenth century that took a heavy toll of life in both England and America. This is not to say that there were no epidemics in America between 1725 and 1800, but with the exception of a few port cities, outbreaks of epidemic diseases appear to have been much milder than in England.

Similar cycles in height appear to have occurred in Europe. Table 4 indicates that average Swedish heights declined by 1.4 cm between 18-III and 18-IV. Hungarian heights declined sharply (5.2 cm) between 18-III and 19-I. There may also have been a slight decline in the mean final height of the French between the second and third quarters of the nineteenth century. Although Table 4 does not reveal it because heights are averaged over quarter centuries, there also appears to have been regular cycling in English final heights throughout the nineteenth century. Although the amplitude of these cycles was moderate, they are statistically significant (Floud, Wachter, and Gregory 1988). The use of quarter century averages in Table 4 also disguises some height cycles in Sweden. During the second half of the 1840s and in the 1850s heights declined sharply in Stockholm and in southern Sweden generally. This decline in heights was accompanied by a rise in infant mortality rates (Sandberg and Steckel 1988).

This evidence of cycling in stature and mortality rates between 18- III and 19-III in both Europe and America is puzzling. The overall improvement in health and longevity during this period is less than might be expected from the rapid increases in per capita income indicated by national income accounts for most of the countries in question (Maddison 1982; Crafts 1985). More puzzling are the decades of sharp decline in height and life expectation, some of which occurred during eras of undeniably vigorous economic growth. This conflict between vigorous economic growth and very limited improvements, or reversals, in the nutritional status and health of the majority of the population suggests that the modernization of the nineteenth century was a

Figure 5

A COMPARISON BETWEEN THE TREND IN THE MEAN FINAL HEIGHT OF NATIVE-BORN WHITE MALES AND THE TREND IN THEIR LIFE EXPECTATION AT AGE 10 (e^o_{10})
(height by birth cohort; e^o_{10} by period)



mixed blessing for those who lived through it. The problem at hand, then, is the identification and measurement of the negative aspects of modernization that temporarily offset such benefits as the leap forward in scientific knowledge, the remarkable technological innovations in agriculture, transportation, industry, and commerce, and the marked gains in labor productivity.

Research into this problem so far has focused on four principal possibilities. These are rapid urbanization, increased geographic mobility, increases in population more rapid than the food supply, and increases in the inequality of the distribution of income. At the present stage of knowledge, discussion of the relative importance of these factors in temporarily offsetting the benefits of increased productivity must of necessity be speculative, but may suggest fruitful lines of further research.

Although the mix of factors tending to retard improvements in nutritional status and health varied from one country to another, one factor stands out more than any other: rapid urbanization. Both in Europe and America the population of cities during the nineteenth century grew far more rapidly than at any other time in history (Wrigley 1969; Bairoch 1988). The mortality rate appears to have been influenced both by the size of the city and by the rapidity of its rate of growth. In the U.S. case c. 1830, cities with 50,000 or more persons had more than twice the death rates of rural areas (Vinovskis 1972; Fogel et al. 1978) and similar patterns have been observed for Europe (Weber 1899; Woods 1984; Bairoch 1988). The exact threshold at which city size began to affect mortality rates varied with time, place, and circumstance, but in the U.S. during the mid-nineteenth century, cities of about 25,000 persons appear to have been the threshold of significant elevation in mortality rates.[11]

Increased geographic mobility had an independent effect on mortality rates. A classic example is the spread of the cholera epidemic of 1849-1850 in the U.S. This epidemic was brought to American shores in December of 1848 by two ships carrying German immigrants, one bound for New York, the other for New Orleans. Although New York-bound passengers who were sick with cholera when the ship arrived were kept in quarantine, others were allowed to enter the city. Within a few days cholera broke out in the immigrant districts of New York: later it spread to the predominantly native-born, lower-class districts nearby; and eventually to upper-class districts. In the case of the ship bound for New Orleans, public health officials were not only able to tie the spread of disease to New Orleans with the disembarkation of the immigrants there, but to follow the movement of cholera up the Mississippi and its tributaries. As immigrants from the infected ship boarded river steamers, cholera broke out about these ships and then in the cities at which the steamers called, including Memphis, Nashville, Louisville, Cincinnati, Wheeling (new W. VA), Pittsburgh, and St. Louis. Soon after it reached these cities, cholera broke out in the surrounding countryside (U.S. Surgeon General, 1875).

Despite the drama of the cholera epidemic, internal migration was probably more important that foreign migration in spreading disease in the U.S. during the nineteenth century. The migration of many Easterners to the Midwest via New Orleans appears to have been a major factor in making malaria endemic in the Midwest as far north as Madison, Wisconsin, during the 1820s, 1830s and 1840s (Boyd 1941; Ackernecht 1945, 1952; Drake 1850, 1854; Coolidge 1856). The upsurge of malaria in the North following the Civil War appears to have been the consequence of the return of large numbers of Union Army men who became infected with the plasmodium while serving in the South (Ackernecht 1945; Boyd 1941).

In addition to their independent effects, there was an important interactive effect between urbanization and migration. The overcrowded housing, the crisis in public sanitation brought on by decades of exceptionally rapid population growth, and the poor personal sanitation of tenement dwellers made the large cities of Europe and America reservoirs of disease that not only undermined the health of urban residents but also served to infect the surrounding rural areas. The mechanisms through which urban diseases were transmitted to the countryside were trade (Landes 1969) and the rotation of labor between the cities and the surrounding countryside. Recent studies have revealed that in addition to providing a stream of permanent migrants to the city, the countryside provided a large stream of temporary laborers. Perhaps two or three times as many rural residents rotated work between the city and the countryside as left the countryside permanently (Goubert 1973; Vries 1984). Thus trade and labor rotation carried such diseases as typhoid, typhus, dysentary, cholera, and other major killers of the nineteenth century from the city to the countryside.

The pressure of population on the food supply may have played some role in the cycling of heights. Komlos (1985 and 1988) argues that this was the case in Hungary between 18-III and 19-I and Sandberg and Steckel (1988) provide a similar explanation for the decline in heights and the rise of infant mortality rates in southern Sweden during c. 1840 - c. 1860. However, such general pressure on the food supply does not seem to be a likely explanation for the U.S. decline in heights and in life expectation shown in

Figure 5. Calories available for human consumption appear to have increased between 1840 and 1860.[12] In any case both average calorie and protein consumption were high throughout the period of decreasing stature and life expectation, exceeding 3,600 calories and 120 grams of protein per consuming unit daily.[13] These levels are in excess of current recommended daily allowances for males engaged in heavy work for 3,300 hours annually (FAO/WHO/UNU 1985, pp. 71, 77, 79).

The fact that average food consumption of Americans (gross nutrition) remained high during 1830-1860 does not imply that the average amount of nutrients available to sustain physical development (net nutrition) remained high. Indeed, the fact that average stature declined by several centimeters implies that either an increasing amount of the food ingested failed to be metabolized or that claims on the intake of food were increased. The increased prevalence of malaria in the North associated with the increased migration of persons bound for the Midwest through New Orleans, the apparent rise in diarrheal diseases (including cholera and typhoid) both in the cities and countryside, and the increased incidence of typhus, tuberculosis, and respiratory infections, measles, and other crowding diseases associated with rapid urbanization after 1820 provide the mechanism necessary to reconcile a high level of food consumption with the observed decline in stature (Ackernecht 1945; Boyd 1941; Smillie 1955). Increases in the incidence of such diseases could have reduced nutrients available for growth because of the diversion of nutrients to fighting the diseases, decreased absorption of nutrients, reduced appetite, and the poorer quality diets that are often fed to the sick (<u>J. Inter. Hist</u>. 1983; Taylor 1983; Scrimshaw, Taylor, and Gordon 1968).

Since permanent stunting occurs largely at ages under age three (Tanner 1982; Billewicz and McGregor 1982; Horton 1984a and 1984b; Martorell 1985; Martorell and Habicht 1986), declines in final heights during the nineteenth century raise questions about the synergism between nutritional status and disease in utero and in early childhood. Physical development before age three could have been retarded because of increased infections of pregnant mothers, because of increased contamination of foods fed to young children, because of increased use of elixirs containing opiates that were used to pacify infants, and because weaning and early childhood diets were low in protein. Early childhood diets that were marginally inadequate in protein when exposure to disease was low could have become severely inadequate as the incidence of disease increased. Since disease interrupts growth, the amount of protein required to bring about full catch-up growth following an episode of infection may be many times the normal requirement (Scrimshaw, private communication; Whitehead 1977). In the U.S. case, an increase in the proportion of time in which children under age three were sick or in the process of recovery could explain the sharp decline in final heights despite the large and relatively constant quantities of meat consumed by older persons during 1840-1860.

Increases in the inequality of the distribution of income (and hence of the consumption of nutrients) could also explain the periodic declines in stature during the nineteenth century. This factor could have been at work, particularly during depressions that sharply increased unemployment among manual workers and reduced their real wages. The fact that the heights of the British upper classes did not exhibit the same cycling in stature as found among the laboring classes, and the correlation between the real wages of urban workers and stature suggests that there may have been cyclical surges in inequality, even if there was no marked secular increase in inequality in Britain between 18-III and 19-III (Floud, Wachter, and Gregory 1990; Lindert and Williamson 1982 and 1983; Williamson 1985; Feinstein 1988). Sharp declines in the real wages of nonagricultural manual workers appear to have been a factor in the U.S. case as well (Williamson 1976; Margo and Villaflor 1987; Fogel and Engerman 1990; and Fogel, Galantine, and Manning 1990). However, even those who prospered during 1840-1860, such as the farmers, experienced sharp decreases in stature. In the American case about four-fifths of the decline in average stature between 1830 and 1860 took place among rural populations that prospered (Fogel 1986b).

Principal Mechanisms for the Escape from High Mortality: Thesis 10

The decline in mortality rates over the past hundred years is one of the greatest events in human history. The paper published by McKeown and Brown in 1955 marked a turning point in the effort to provide a warranted explanation of the decline in mortality. Bridging the worlds of social scientists and of medical specialists, they brought into the discussion most of the range of issues that have been under debate for the past three decades. That debate not only defined the issues more clearly than previously, but also revealed that the critical differences were quantitative rather than qualitative. Nearly all the specialists agree that improved nutrition, improved public and personal sanitation, decontamination of food and water, improved housing, and advances in medical technology were responsible for the decline in mortality, but they have had quite different views about the relative importance of each of the factors. The unresolved issue, therefore, is not really whether a particular factor was involved in the decline, but 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, which involves measuring not only the direct effect of particular factors but also their indirect effects and their interactions with other factors.

The complexity of the measurement problem is indicated by the statement earlier in the paper that 50 to 60 percent of the decline in mortality rates in England, France, and Sweden between 18-IV and 19-III was due to improvements in stature and body mass. These results indicate that the elimination of chronic malnutrition was a major factor in the decline in mortality, but they do not indicate how much of this portion of the decline was due to improvements in the diet and how much was due to such other factors that affected stature and body mass as the decline in the incidence of infectious diseases. Although work on this question is still at an early stage and the eventual outcomes of many issues are hard to predict, several points already established are worth noting.

It appears that the average level of caloric intake and of protein consumption was so low during the last quarter of the eighteenth century in both England and France that large proportions of the population were bound to have been vulnerable to high morbidity and mortality rates. Moreover, while there were improvements both in the per capita supply of food and of its distribution between 18-III and 19-III, the improvements were modest by comparison with the advances of the twentieth century. In France, for example, it was not until 19-II that the average daily caloric consumption reached levels currently prevailing in India. Although French caloric intake increased by nearly 50 percent between c. 1830 and c. 1880, meat consumption remained relatively low, averaging just 69 pounds per capita during 19-III or less that two-fifths of the U.S. level of consumption in 1880 (Toutain 1971; Holmes 1907; Bennett and Pierce 1961).

To see the figure on average meat consumption in its proper perspective, it is important to keep in mind that the distribution of meat was much more unequal than that of calories. We do not yet have reliable estimates of the inequality of the meat distribution for European nations in the mid-nineteenth century. However, even a highly egalitarian distribution (Gini = 0.22) implies that the average annual meat consumption of the bottom half of the French population during 19-III was about 47 pounds, and a distribution of meat as unequal as that for income in England during the nineteenth century (Gini = 0.5) implies that the lower half of the population consumed an average of just 23 pounds annually (Feinstein 1988). So even when France approached adequate average levels of meat consumption, perhaps as much as a quarter of the population were still consuming less that an ounce of meat per day.

Such low levels of meat consumption, when compared with current standards, were not confined to France. Available evidence suggests that annual meat consumption at the turn of the twentieth century was below 75 pounds per capita in Sweden, Norway, and Austria-Hungary. British consumption, the highest in Europe, probably averaged about 100 pounds per capita annually (Holmes 1907; Fogel 1989).[14] It was not until after World War II that these nations reached levels of meat consumption achieved in the U.S. more than a century earlier (U.S. Bureau of the Census 1967, p. 874; U.S. Central Intelligence Agency 1978; Peach and Constantin 1972).

The fact that the U.S. diet of the midnineteenth century provided enough high-grade protein to permit considerable catch-up from the interruption in growth caused by disease goes a long way toward explaining why the final heights of native northern white farmers born c. 1830 averaged 68.7 inches. Yet without any apparent deterioration in their diets, the final heights of farmers born c. 1860 averaged only 67.2 inches, 1.5 inches below their earlier level, and almost 3 inches below levels of white American males born c. 1955 (Fogel 1986b and U.S. Dept. of Health and Human Services 1987). These differentials suggest the magnitude of stunting of even well-fed males in a severe disease environment. The apparent final height of the London poor c. 1800, which was about 62 inches (Tanner 1982), may be taken as representing the combined effect of exceedingly poor diets and exposure to exceedingly severe disease environments, while 70 inches (the average final heights of U.S. white males today) may be taken to approximate the combined effects of a relatively good diet and a mild disease environment.[15] These figures suggest that even with good diets, continuous exposure to a severe disease environment will lead to stunting of about three inches, which is about 40 percent ($3 \div 8 = 0.4$) of the stunting associated with the combined impact of severe exposure and diets barely above maintenance. Moreover, with the BMI held at its optimal level, 3 inches of stunting increases the risk of death by about 21 percent.

The Contribution of Improved Nutrition and Health to the Growth of Labor Productivity: Thesis 11

The first law of thermodynamics 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. However, that level of work 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 2.1 hours of heavy work or about 3.7 hours of moderate work per day.[16]

It is quite clear, then, that the increase in the amount of calories available for work over the past two hundred years must have made a non-trivial contribution to the growth rate of the per capita income of countries such as France and Great Britain. That contribution took two forms. First, it increased the labor force participation rate by bringing the bottom 20 percent of the consuming units who, even assuming highly stunted individuals and low BMI's, 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.[17] 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 percent to the annual British growth rate between 1780 and 1980 ($1.25^{0.005} - 1 = 0.0011$).

However, 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.[18] 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.[19] 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,[20] then the increase in the amount of energy available for work contributed about 0.23 percent 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).[21] 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. Although it is my guess that these two influences tend to cancel each other out, it may be that the share of energy 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.[22] 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.

NOTES

1. I am indebted to David Weir for supplying Figure 1, which corrects a typographical error in the version of that diagram published in Weir 1984. Both the French and the English series are eleven year moving averages, centered on the years shown. Weir's sources were Wrigley and Schofield (1981), pp. 531-535; INED (1977), pp. 332-333; and Mitchell 1980, pp. 116-119.

2. The English cdr in 1980, both sexes combined, and standardized on the age structure of 1701-5, is 7 per 1000 (Fogel 1986b, p. 440).

3. The F-value for $\frac{s_3^2}{s_2^2}$ and of $\frac{s_4^2}{s_2^2}$ are significant at the 0.004 level (the periods referred to by the three subscripts are 1600-1640 for 2, 1641-1699 for 3 and 1700-1745 for 4).

4. For a more extended discussion of this point see Fogel 1988b, section 2.1.

5. The main conclusions summarized in this section are robust to any value of the coefficient of variation in the range 0.3 ± 0.1.

6. This discussion only takes account of the incidence of mortality among those in each country whose consumption of calories was below basel metabolism. However, there were many other individuals who were at increased risk of death because they were malnourished, even though the degree of malnourishment was less extreme. See pp. 29-33 and n. 10.

7. Even small amounts of common agricultural or urban manual labor would have put such malnourished individuals on a path toward consuming their own tissue, and if continued long enough, would have, sooner or later, resulted in death. These are the people who constituted Marx's _lumpenproletariat_, Mayhew's "street folk," Huxley's "substrata," King's "unproductive classes" consuming more than they produced, and the French _gens de néant_ (Himmelfarb 1983; Laslett 1984).

8. For a further discussion of this possibility see Fogel 1988b. It is important to keep in mind that the denominator of the relative risk curve is

the average mortality rate computed over all heights. Consequently the curve will shift as the overall mortality shifts. What appear to be stable over a wide range of mortality regimens are the height-specific relative rates.

9. As with height, these curves have the average mortality rate, calculated over all BMI's, in the denominator. Compare the discussion in note 8. The body mass index used here, weight-measured in meters (kg/m^2), is referred to as the Quetolet index. Epidemiologists use height-squared rather than height in the denominator because that transformation reduces the correlation between height and the BMI to low levels in cross section.

10. The English cdr for c.1790 is 26.7 and 1.35 times that number is 36.0, which is virtually identical to a French cdr of 36.1 derived from Weir's data.

11. This statement relies on the use of height data as a proxy for mortality rates. In regressions relating final heights of native-born white males to socioeconomic factors, dummy variables for city-size did not become significantly negative until the dummy for 25,000-49,999. For similar results based on direct measurement of mortality see Vinovskis (1972).

12. Komlos (1987) has argued for a slight decline in caloric intake between 1839 and 1859, but this result is based on the assumption that human corn consumption was just 4 bushels per capita throughout the period, despite the rise in output per capita and in output per consuming unit (including livestock) of about 56 percent (Fogel 1965, p. 206). An increase of human corn consumption by about half a bushel per capita annually between 1840 and 1860 wipes out the small decline in calories postulated by Komlos. The large increase in corn feed per consuming unit also casts doubt on his assumption that the slaughter weight of livestock remained constant.

13. See Fogel and Engerman 1974, II:92-99 and 1989b, for the procedures followed in obtaining these estimates. It should be kept in mind that corn, peas and other widely consumed vegetables are major sources of protein. Consequently, contrary to Komlos's (1987) assumption that average protein consumption per capita declined between 1839 and 1859, it may have increased slightly not only because average meat consumption may have increased but also because of an increase in the availability of vegetable sources of protein. In any case, Komlos's estimates (1987, table 8) imply that during 1840s and 1850s consumption per equivalent adult male was about 3,700 calories and 125

g. of protein.

14. It should be noted that the figures in Holmes' Table 59 need to be converted from dressed weight to edible weight. In the British case I followed him in assuming that imports were close to edible weight but that domestic production represented dressed weight. To convert dressed to edible weight (excluding lard) I used 0.64 ($0.47 \div 0.73 \approx 0.64$). This is the factor for swine and is somewhat higher than for cattle and sheep (Holmes 1907, pp. 60-63).

15. The content of the diet of northern farm children under age 3 c. 1850 is still an open issue.

16. I have assumed a height of 160.5 cm and a weight of about 49 kg. These assumptions imply a BMR of 1,372 kcals and 1,742 kcals for maintenance, leaving about 451 kcals for work. Heavy work (including rest breaks) requires 219 kcal per hour, moderate work (including breaks) 122. Hours of work per day are calculated on a basis of 365 days. If one assumes a work year of 250 days, allowing for holidays sickness, then the figures become 3.1 hours of heavy work and 5.4 hours of moderate work <u>per working day</u>. The last pair of figures still do not standardize for slack days and inclement days, when only indoor work of a sedentary nature was performed. Adjusting for such days would further increase the number of hours of heavy work and moderate work normally performed during such key seasons as planting and harvesting.

17. It was assumed that the bottom 20 percent of the English consuming units were 157 cm tall, with a weight of about 47 kg, which implies a BMR of about 1,342 kcal and about 1,704 kcal for maintenance. The estimated average caloric intake of the second decile of the English caloric distribution in 18-IV was 1,903 kcal. Strolling requires about 76.56 kcal 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 kcals above maintenance, and 335 kcal above maintenance while engaged. Computed from the requirements in FAO/WHO 1985, p. 76.

18. Calories per capita in 1980 were converted to calories per consuming unit, using the age sex structure of the British population in 1980 (G.B. Cent. Stat. off. 1987) 19. It was assumed that in 18-IV mature males ages 23-29 were 167.9 cm tall, with a BMI of 21.7 (see Fogel 1988b; Table 7 and 9 above), so that their mean weight was 61.2 kg. Such men would require 1,524

kcal for BMR and 1,935 for maintenance. The corresponding figures for 19-III were 175 cm, 24.0, and 73.5 kg. The BMI figure is the average of those for the B.P. staff and business executives in Eveleth and Tanner (1976, p. 285). These imply 1,679 kcal for BMR and 2,132 for maintenance (Quenouille et al. 1951).

20. There was probably an increase in hours worked per week between 18-IV and 19-II and a decrease thereafter. However, intensity of work per hour may have increased steadily in Britain throughout the past two centuries.

21. Not a great deal is known about how disability days have varied over time. It has been estimated that U.S. slaves c. 1850 had an average of 12.7 disability days. U.S. blacks averaged 14.8 days in the late 1890s, 16.2 days in 1970 and 21.7 in 1981. For the entire civilian U.S. population the annual number of disability days rose from 16.4 per capita in 1965 to 19.1 in 1981. Interestingly, over this period the number of disability days per capita rose for persons under age 65 but not for those over 65, which suggests that this measure may be strongly influenced by cultural or social norms including the days of sickness pay in labor contracts (Fogel and Engerman 1974, II, p. 101; U.S. Bur. Cen. 1983, p. 121). Riley and Alter (1987) have found an upward shift in the age-specific schedule for the duration of illness between 1866-70 and 1893-97 in a sample of English Odd Fellows, which they attribute to a decline in the case mortality rate.

22. See Osmani 1987 for an extended summary of the literature.

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