Population, Food Intake, and Fertility

There is historical evidence for a direct effect of nutrition on reproductive ability.

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In many historical populations, couples living together to the end of their reproductive lives produced an average of only six or seven children (*1–3*). Poor couples in many developing countries today also average only about six live births (*4, 5*). Six children per couple today results in a very rapid rate of population growth because of decreased mortality rates, but this number is far below the average maximum of 11 or 12 children produced by well-nourished peoples such as the Hutterites, who do not practice contraception (*6, 7*). The usual explanation of the lower than maximum fertility in both historical and contemporary societies is that it is due to the use of "folk" methods of contraception, or to abortion or venereal disease, in combination with social customs such as late age of marriage or a taboo on intercourse during lactation (*2, 8*). But differences in natural fertility have been recognized (*9*) and explained by biologically different intervals between births (*9, 10*).

The purpose of this article is to show that undernutrition and "hard living" may be an explanation of the lower than expected fertility of mid-19th-century English and Scottish populations. Historical data on reproduction, physical growth, and nutrition will be presented in support of the hypothesis that reduced reproductive ability (subfecundity) of women and men in the lower socioeconomic classes, and a lesser degree of subfecundity plus a late age of marriage in the upper socioeconomic classes, were the main reasons that married couples of those times produced only six to seven children.

The Vigor or Decrepitude of the Reproducing Individual

Quantitative interest in the body in relation to nutrition, growth, and reproductive ability in both sexes was strong in the 19th century (*1, 11, 12*), probably inspired by Quetelet's pioneer work (*13*). In the earlier Malthusian view, human reproductive power is an irrepressible force, fulfilling itself regardless of circumstance, to be cut down by the positive check of increased mortality, or held in check by the moral restraint of late marriage (*14*). In contrast, the medical and biological literature of 1850 to 1880 expresses the view that reproductive ability in both sexes is directly related to the state of vigor or decrepitude of the reproducing individuals. The individual does not reproduce the species at any cost, like a salmon breeding and dying. Instead, if the choice is individuation versus genesis, individuation wins (*15*). When food supplies are inadequate, women and men, like other mammals, are less fecund. When food intake is very low, reproduction stops (*11*).

Darwin described this commonsense relationship between food supplies and fertility, observing that (i) domestic animals which have regular, plentiful food without working to get it are more fertile than the corresponding wild animals; (ii) "Hard living retards the period at which animals conceive" (*16*); (iii) an individual's fertility is affected by variations in the amount of food (*16*); and (iv) it is difficult to fatten a cow that is lactating (*17*). As I will show, all of Darwin's dicta apply to human beings, including the difficulty of fattening a lactating woman (*18*).

The Synchronization of Growth and Reproduction

Nutrition, hard work, and disease can affect the fertility of women and men because reproduction requires energy (*19*) and because reproductive ability (fecundity) is synchronized with physical growth and development (*20*). In the human female the onset and maintenance of menstrual cycles are each associated with the attainment of a minimum weight for height representing a critical fat store (*21*). The undernourished female has menarche later and menopause earlier than does a well-nourished female. The undernourished female has a high frequency of irregular and anovulatory cycles, and menstruation stops completely if undernutrition is severe. During pregnancy an underfed woman has a higher probability of a miscarriage and of a stillbirth (pregnancy wastage) than a well-nourished one and if she delivers an infant successfully her lactational amenorrhea is longer after parturition, resulting in a longer birth interval (*19*).

In the adult male, severe undernutrition results in loss of libido, a decrease in prostate fluid, a decrease in sperm number, a loss of sperm mobility and, eventually, the cessation of sperm production, in that order (*22, 23*). Undernutrition also delays the onset of sexual maturation in boys (*24*) and girls (*25*). Both male (*23*) and female (*1, 6, 9*) fecundity decline with age; the male decline may be more rapid with undernutrition, as it is in the female (*1*).

There is thus a direct pathway from food intake to female and male fecundity to fertility, in addition to the classic indirect Malthusian pathway through mortality (*19*). Carr-Saunders (*26*) gives many examples from hunting and fishing societies to show that poor conditions limit human fecundity and better conditions increase it. Two modern examples of the direct effect of nutrition on fertility are: (i) the increase of the fertility of the Hutterites from 1880 to 1950, in association with an increased standard of living (*7*); and (ii) the changes in fertility of a noncontracepting Bangladesh population in correlation with the food supply (*5, 27*).

Reproduction Requires Energy: The Historical View

Medical texts up to about 1885 state that constitutional reasons for sterility are more important, and more prevalent, than sterility due to diseases of the organs (*1, 28–30*). It therefore is not always wise to cure sterility: A sterile woman may be deficient in reproductive energy; if she did conceive there would be a high risk of miscarriage, or of weakly children being produced, or of the mother dying in childbirth (*11*, p. 113).

The degree of pinguidity—fatness—

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was considered important in relation to sterility (*11, 28*) [see also (*31*)]. "She's too thin to get pregnant," or "to menstruate regularly," were common observations, especially in association with tuberculosis or chlorosis, a virulent anemia common among working-class women, which colored them a sickly green (*29, 32, 33*). The prescription was : "recover her flesh" by giving her puddings, roast meats, a good wine, fresh air, and sun (*32*).

"She's too fat to get pregnant," was also observed (*11, 28, 32*), [excessive fatness causes amenorrhea (*31*)]. A light diet and exercise were prescribed (*32*).

The observation that women often got fatter after menopause was explained by the fact that a female no longer expended energy in creating "that most subtle human extract, the ovum" (*28*, p. 105).

The Curve of Procreative Power: Age-Specific Fertility

The fertility of women gradually increases with age to a climax and then gradually wanes (Fig. 1) (*1, 6*) in a manner similar to "the fertile career of the domestic hen" (Fig. 2), Dr. Duncan advised the Royal College of Physicians in 1884. Reproductive errors are more frequent at the beginning and end of the fertility curve: "an old bitch often ends her career of breeding by a dead or premature pup" (*1*, p. 168).

The fertile career of the mid-19th-century female began with (i) the "age of commencing menstruation" (menarche) at about 15 to 16 years. It was already observed that a period of relative infertility (now termed adolescent sterility) (*34*) followed menarche. This period lasted until the completion of physical growth at about 22 years of age, when (ii) fitness for procreation was attained. Then came the rise to the climax: (iii) the age of nubility, or best fitness for procreation, at about 25 to 29 years of age. This was the age of full physical vigor (Fig. 1) when a woman had the best chance of surviving her first birth (*1*, p. 311). The curve descended gradually to (iv) the age of cessation of childbearing, at about 40 years, and then to (v) the cessarion of menses, the menopause, at about 47 years of age (*11, 29*).

The risk of maternal mortality, infant mortality, and congenital deformities decreased from menarche up to the age of nubility (25 to 29 years) (*1*, p. 311) and then increased with the increasing age of the mother. A "turning-off" period of premenopausal sterility between the end of childbearing and the ending of menstrual cycles was noted, analogous to the "turning-on" period of adolescent sterility (*1*). In the mid-19th century, these periods were of about equal length, 6 years (*29*).

According to the Scottish data, the fertility of women before age 30 years was more than twice as great as after 30 years (*1*). This suggests that the age of marriage could affect subsequent fertility more sharply a century ago than in the modern era, when the curve for age-specific fertility does not decline so rapidly (Fig. 1).

Reproduction and Physical Growth

The medical texts up to about 1880 reflect the view that each reproductive stage relates to physical growth and the coordinated growth of the genital organs, which "arrive latest at perfection and are the first to become worn out and decrep-

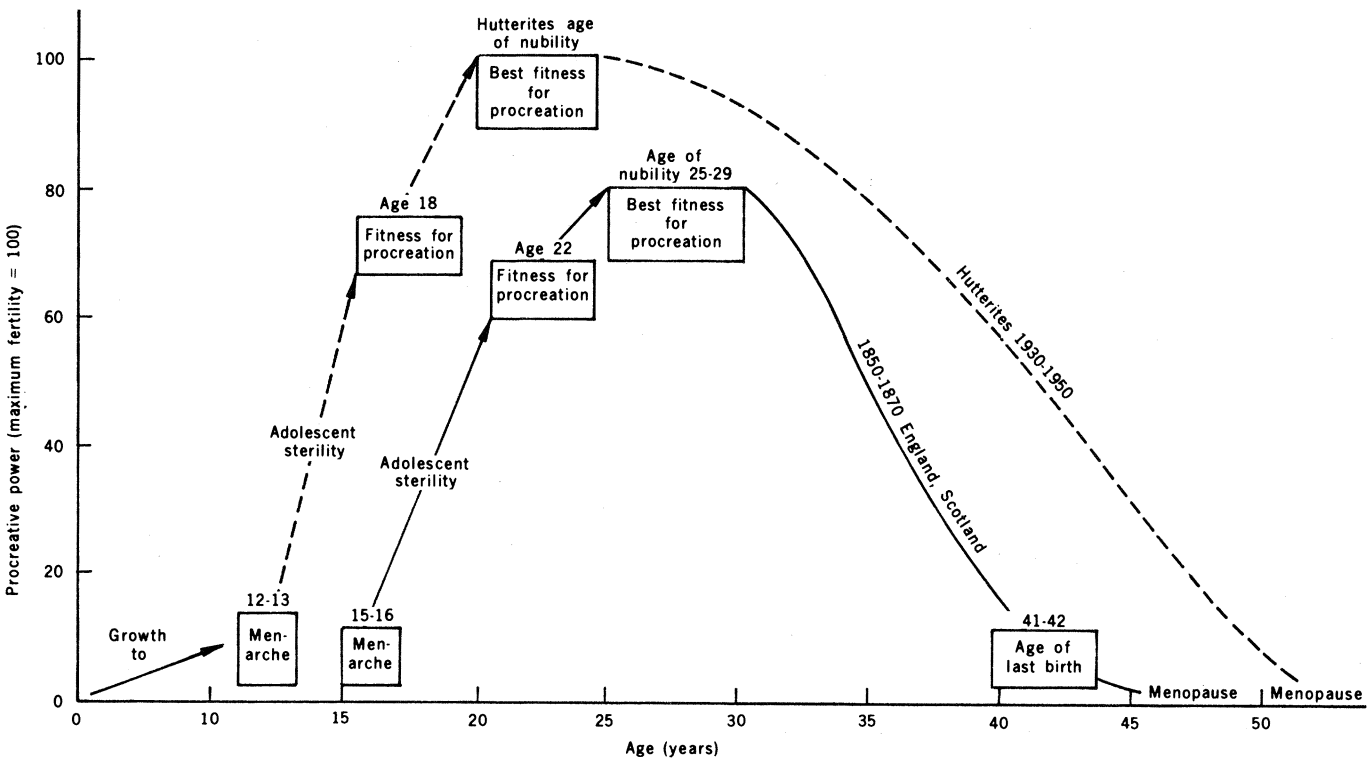


Fig. 1. The curve of female procreative power in the mid-19th century (variation of the rate of childbearing with age) compared to that of the well-nourished, modern Hutterites, who do not practice contraception. Hutterite maximum fertility is taken as 100 (*6, 9*). The ages of menarche and adolescent sterility of the Hutterite curve are based on data for contemporary girls in the United States (*20, 31*). The age of menopause is based on data for contemporary women in the United States (*50*). The maximum level for the mid-19th century is scaled and timed according to historical age-specific fertility data (*1*, p. 311; *9*; *11*, p. 26; *79*). The ages of other reproductive events are based on historical data described in the text. The longer reproductive span of the modern well-nourished population reflects the secular trend to an earlier menarche and later menopause associated with better nutrition, more rapid growth in height and weight, and earlier attainment of adult size. The earlier, higher level of peak fertility found with the longer reproductive span also can be explained by the effects of improved nutrition on reproductive ability (see text). The fertility schedule of the Hutterites results in about 10 to 12 children, depending on the age at which the women marry (*7, 9, 45*); the fertility schedule of women in 1850 to 1870, in about 6 to 8 children (*1, 6, 9*). The timing and levels of the historical curve are approximate.

it" (35). If a female, human or cattle, is bred too young, it is "at the expense" of the completion of normal growth, and may result in both an inferior offspring and the death of the mother. Duncan studied the age-specific fertility data of Edinburgh to find the age of reproduction that was of least risk to the mother. "If a woman is to multiply and replenish the earth, as married women ordinarily do, she must survive her first confinement" (1, p. 387). This was not easy in 1850 to 1860, since the mortality of Scottish mothers having their first child was twice as great as that of all subsequent births combined (1, p. 304). The recommended age of marriage of 25 years for the female was based on the survival rates from the fertility data, and the data on the late completion of normal growth of the uterus (about 22 years) (19) and the bony pelvis (about 25 to 30 years) (1). The interest in the changes of dimensions of the pelvis with age is understandable since fetal craniotomies were often performed to save the life of the mother (36, 37).

Social Class Differences in Age of Menarche

The average age of menarche in mid-19th-century Britain was 15.5 to 16.5 years (1). Menarcheal age diffiered by social class, upper-class women having menarche 0.5 to 1 year earlier on average than working-class women (1, 29, 38–40). Undernutrition and hard living were the explanations given for the class differences and for the great variability in age of menarche which ranged from 10 to 26 years in the working class. A girl who did not have menarche by age 17 or 18 years was considered to be in a weak state of health (29). Girls who had menarche at 11.5 or 12.5 years were considered to be cases of precocious puberty (39). [The average age of menarche in the United States is now about 12.5 to 12.8 years (20, 41).] The heights, weights, and body compositions of the 19th-century females showing precocious puberty (39) are similar to those observed at menarche for normal contemporary girls.

Norwegian data on changes in menarcheal age from about 1830 to 1930 show the disappearance of class differences in age of menarche as the average age became earlier, as would be expected with the gradual equalization of diet and mode of living among the social classes (42).

Traveling doctors collected menarcheal data for foreign populations for comparison with local data. For example, black slave women in the West Indies, where food was poor and physical work hard, had menarche at about age 16 years, similar to the English working class (40). Psychological influences, such as "premature indulgence of the sexual appetite," were also considered as a cause of earlier age of menarche. This explanation is given for reports of early puberty (12.6 to 13 years) in Asian females (40).

Whitehead (29) had a strong argument against the theory of lax morals causing early puberty: If this were so, we should find puberty occurring earlier in the laboring and destitute females of large towns than among the upper classes. But we find the very reverse: the upper classes are earlier, sometimes by as much as 16 to 18 months. Yet surely virtue is not less cherished in the upper class? Warming to his subject, Whitehead points out that young females employed in shops, factories, and houses as domestics are constantly in "unavoidable collision" with the opposite sex "a grade above them," and many of the latter employ "artifices" to bring ruin and disgrace upon the creatures they should protect. "It is a wonder that any escape childhood uncontaminated." These observations also suggest low marital coital frequency in the upper classes.

Evidence for Subfecundity

About a quarter of the women working in the mills suffered from either "retarded or suppressed" menses. About half of all married women between the ages of 20 and 45 years were reported to have "diseases of the uterus," which included amenorrhea (29, 30). Leucorrhea, the "whites," and its cure is a standard topic in medical texts (30). Prolapsed uterus was another common problem among women of all social classes (29, 43).

The main causes given for amenorrhea were those which "impair the constitutional tone and impoverish the blood" (30): poor diet, disease, particularly tuberculosis and chlorosis, unsuitable employment, and cold and damp. Doctors noted that working-class women were underweight and amenorrheic because of poverty; upper-class women because of their desire to be fashionably thin (30). Stress (violent fits of passion) was also noted as a cause of amenorrhea (29).

Remedies to "bring on the changes" (menses) ranged from hot gruel and gin to "enrich the blood and heat the system" (29) to the use of a long list of emmenagogues, such as aloes. Medical texts distinguish emmenagogues from abortifacients, which seem to have been little used (29, 33).

The Incidence of Absolute Sterility

Absolute sterility (no children by 3 years after marriage) occurred in about 15 percent of the 16,301 married women of ages 15 to 44 years in the Edinburgh study (1). Other surveys in England estimate sterility at about 10 percent (1). Among upper-class marriages, Ansell reports that 8 percent were childless and 7 percent had only one child (44). The modern Hutterite women have about a 2 percent incidence of absolute sterility (45).

The Length of Birth Intervals

Lactation (nursing) was regarded as the regulator of the birth interval in the human female, as in the rabbit and other graminivorous quadrupeds (46). The length of the birth interval, in turn, determined the ultimate size of the family and the health of the mother and child (1, 46). The average birth interval for working-class and lower-middle-class women was about 24 months (46). This time interval included unsuccessful pregnancies, which averaged about 1.5 for each woman (1). An even longer birth interval, about 30 months, is characteristic of many women in developing countries today (5, 27).

An average birth interval of about 2 years was considered biologically natural (46). Even Sir William Petty, who tried to prove that the population doubled every 10 years for a century after the Biblical flood, "only lays it down that every teeming woman can bear a child once in 2 years" (47). It was already observed, however, that the birth interval became longer as the mother became older: fecundity is proportional to the number of years a woman's age is under 50 (Tait's law) (48).

It was also observed that women "low in fecundity" bred at greater intervals at all ages, beginning with the first birth (1, 44). This subfecundity is also found in some modern women, as shown by comparison of the time interval from marriage to the first birth according to completed family size, for the 19th-century upper-class women (44) and the noncontracepting Hutterites (45). (The use of contraception by women in 1874 to delay a first birth is unlikely.) When completed family size is low, one to three children, the mothers in 1874 and in 1966 had almost identical time intervals to the first birth, 21.4 and 21.3 months, respectively (*44, 45*).

When all family sizes are considered, however, the upper-class mothers of 1874 had a longer interval from marriage to first birth, 15.8 months, compared to 13.0 months for the Hutterites (*45*). This can be explained in part by the fact that the 1874 women were older at their first birth, since their mean age of marriage was 26 years, compared to 21 years for the Hutterite women (*45*). The husbands in 1874 were also older than those in 1966, which may have reduced coital frequency (*49*). But the Hutterites also are better nourished and better grown than even upper-class women in 1874, and therefore would be expected to be more fecund and to conceive sooner after marriage.

An Earlier Age of Menopause

The average age of menopause in about 1850 was between 45 and 50 years (*11*, pp. 24–27). "Intelligent" women in Manchester and York finished childbearing at 41.7 years and had menopause at 47.5 years (*29*). These ages are considerably lower than those for present-day Hutterite women, some of whom still have children at ages 45 to 49 years (*7, 45*). The average age of menopause for present-day women is about 50 years or more (*50*). The mean age of cessation of childbearing for Ansell's upper-class women was 38 years (*44*). That this age is earlier than that of lower-middle-class women may indicate the use of contraception by the better nourished upper-class women. An alternative explanation is that the age of marriage of upper-class men was so late (30 years) that by the time their wives were 40 years of age the frequency of coitus was low (*49*).

Duncan explains an apparent paradox, that women marrying late in life often continue to have children at a later age than the rest of the population, by the fact that when women marry at a late age, only those with high fecundity have children at all (*1*, p. 261). The usual explanation of the earlier ending of childbearing of women marrying at the average age, compared to those marrying late, is the use of contraception (*10*).

The Average Completed Family Size

The Edinburgh and Glasgow women had about seven to eight children by the end of their reproductive lives. Their first child was born, on average, at age 24 years (*1*, footnote p. 109), about 17 months after the marriage ceremony (*1*, p. 131). The age of marriage was therefore about 22.5 years.

The fertility of the English women was about 20 percent less than that of the Scottish women (*1*, p. 235). In St. Georges-in-the-East, a poor part of London, the average number of children "consequent of the prolific marriages" was 5.3 (*1*, p. 111). Duncan notes that this number must be considered very approximate (*1*, p. 112).

Upper-class spinsters married to bachelors at a mean age of 25 years and living in fruitful wedlock until the end of the childbearing period, had a total of 5.7 children (*44*).

The Male Procreative Power and Connubial Absolute Power

The historical curve for procreative power is more speculative for males than for females, but the time of beginning and the peak are reasonably well estimated from the data on the time of fastest growth in height and completion of growth, and the relation to the female ages (*20, 24*). Routh gives the age of peak fecundity in males in about 1850 as 31 to 33 years (Fig. 3), compared to age 26 years for the female (*51*).

The "united, physiological procreative power, female and male combined, determines the size of the family," said Routh in 1850. To help government agencies plan wise emigration policies, Routh calculated "expectant power," which combined the probability of survival with changes in fecundity by age for the female and male. Expectant power added to connubial absolute power gave the "Connubial, Physiological, Procreative Power" from ages 16 to 56 (zero) for wives, and to ages 64 to 65 (zero) for husbands. The absolute, ex-connubial, procreative power of any person was his chance of bringing his "dormant power" into action, in and out of marriage. Routh regretfully concluded that he had not enough data by age in the "criminal connection of the sexes" to assess unmarried fecundity. The figures for absolute connubial power therefore must be considered smaller than they really are (*51*).

Differential Growth Among the Social Classes

The physical growth and development of the poorer economic classes differed significantly from that of the upper classes (*12, 52–54*) (Figs. 4 and 5). The influence of occupation and "sanitary surroundings" on growth and development was shown by data on height, weight, girth of the chest, breathing capacity, strength of arm, span of arms, and sight collected for 83,000 individuals of the British Isles (though, understandably all items are not recorded for all individuals). The growth data show that the well-fed and "most favoured" class (I) were taller and attained final height sooner than the ill-fed and "least favoured" of the community (*52, 54*) (Figs. 4 and 5).

Most men of the lower social classes did not complete height growth until ages 23 to 25 years (*12, 52*); even upper-class men were relatively late, 21 to 23 years (*52*) compared to the present age of completion, age 18 to 20 years, for well-nour-

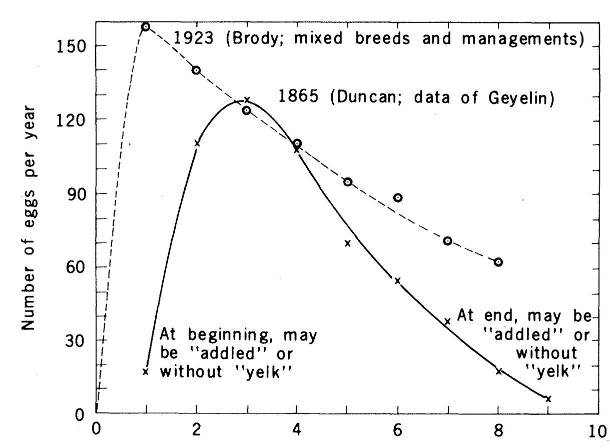


Fig. 2. The number of eggs laid annually by a hen in 1865 [data of Geyelin cited by Duncan (*1*, pp. 36–37)] compared to that of hens in 1923 (*80*) shows the secular trend to earlier egg laying, later cessation, and the earlier, greater maximum fertility of the hens in 1923. Pearl (1909) cites better nutrition, better housing, and "better handling" as reasons for an increase in egg number, in addition to selection for better layers (*81*). (More modern data on egg-laying are not comparable because of 24-hour lighting and other technologies.) Duncan (*1*; *11*, p. 113) used the 1865 hen's fertile career to illustrate the importance of nutrition on fertility. Severe underfeeding and overfeeding reduce egg-laying of the hen to zero, similar to the reduction to zero of the reproductive ability of other animals, including the human female. Reproductive error is greater at the beginning and end of the reproductive span for both the hen and other animals, including the human female (pregnancy wastage) (*11*, p. 78).

ished males (*20a*). Most women did not complete their growth in height until ages 20 to 21 years (*52*), compared to ages 16 to 18 years today (*20*).

The committee noted the "check which growth receives as we descend lower and lower in the social scale." The greatest differences are found at the younger ages, since they also reflect differences in ages of maturation as the committee noted (*52*). Children of ages 11 to 12 years showed a difference of about 13 centimeters between the best and worst nurtured classes, "illustrating the importance of wholesome food, fresh air and exercise."

Not surprisingly, children who worked in factories had the slowest growth and hence latest sexual maturation of any of the groups studied (Fig. 4). The factory employment minimum height and weight standards for boys and girls starting at age 9 years (Fig. 4) were incredibly low. These standards were established not to protect the children but to protect the manufacturers, since parents often overstated the age of their children in order to get them hired. Children who were younger than advertised by their parents did not have the stamina and endurance to last a factory day (*54*).

Height data from Norway, analyzed by social class, corroborate the class differences in growth and maturation found in mid-19th-century Britain. The Norwegian data in addition show the direct effect of an increase in food supply (for example, the introduction of the potato) in valleys in Norway on the height of army recruits, and the age of male and female sexual maturation; the better the food supply, the earlier the maturation (*42*).

The Slow Growth of Men: Did It Affect the Outcome of Wars?

Screening-out the physically unfit from the armed services is especially important when there are large physical differences by social class (*12*). The age, height, and weight for recruits were much discussed and carefully chosen in relation to age of adult physical maturation. The British army doctors who passed on recruits were told that too young an age of recruiting and not enough men at the "acme of virility—35 years" leads to catastrophe (*12*). Poorly fed recruits, the ones most likely to join the army to collect a bounty, were a bad risk since they were physiologically younger than their chronological age. These men were slow to complete their growth so their "limb power" and heart volume were immature. On long marches these were the men who fell by the wayside, or had to be hospitalized (*12, 55*). The youngest recruit should then be at 20 to 21 years—then they will be tone and muscle, "not almost gristle" as Lord Hardinge complained of recruits under 19 years old arriving in the Crimea (*12*, p. 60).

The long list of disqualifying traits for the 19th-century British (and European and United States) armies, including total baldness, fetid sweat, excessive ugliness "if to the extent of repulsiveness," and secondary syphilis (primary syphilis was no bar) attest to the number of infirmities present in the population (*56*).

Food Intake by Social Class

One of the reasons physical growth differed so markedly by social class in the 19th century in Britain was that the quantity and quality of the diet differed by social class. The diet of the laboring class (Table 1) was judged "inadequate for health and strength" (*57, 58*) up to about 1870, when cheap grain and meat began to arrive in quantity from the United States (*59, 60*).

"We are what we eat" was well understood; in fact Smith records that Kean suited the kind of meat which he ate to the part which he was about to play, and selected mutton for lovers, beef for murderers, and pork for tyrants (*57*).

Wheat bread was the main constituent of the working class diet, supplying the major part of the calories and most of the protein of prosperous working class families (Table 1) (*57, 59*). In very poor fami-

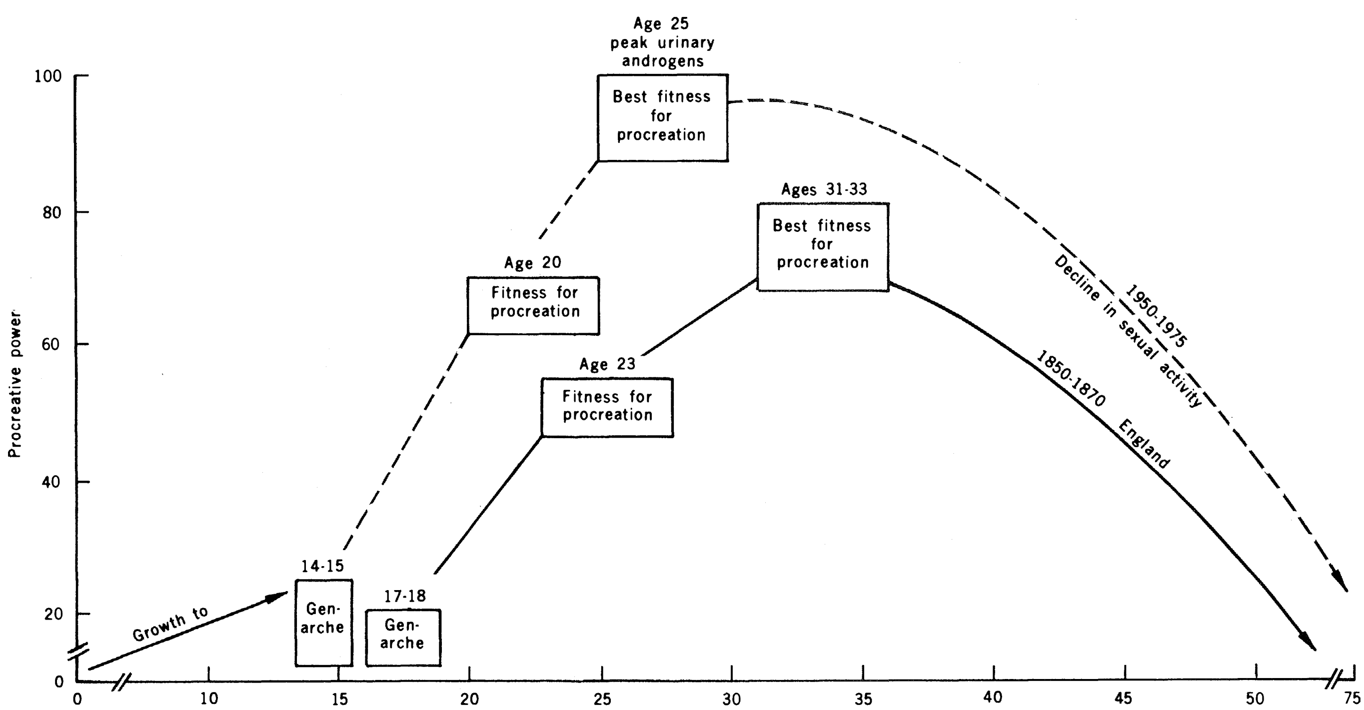


Fig. 3. Hypothetical curves of male reproductive fertility (procreative power) for modern males and males in 1850 to 1870, based on ages of most rapid growth in height, completion of height growth, and hormonal data for modern males (*23*), and the relation to ages of menarche of the female in Fig. 2 (*20, 24*).

lies bread was almost the entire diet, supplemented with small amounts of butter, bacon, cheese, and tea (*59*). Wheat was a symbol of social status and potatoes were at first resisted, especially by agricultural workers. However, the potato became increasingly important in the diet of all working-class groups after 1815, when bread became relatively more expensive (*61*). Rural workers particularly were urged to grow potatoes; half an acre gave 160 bushels of potatoes, which was enough to last through the winter and feed a pig (*57*).

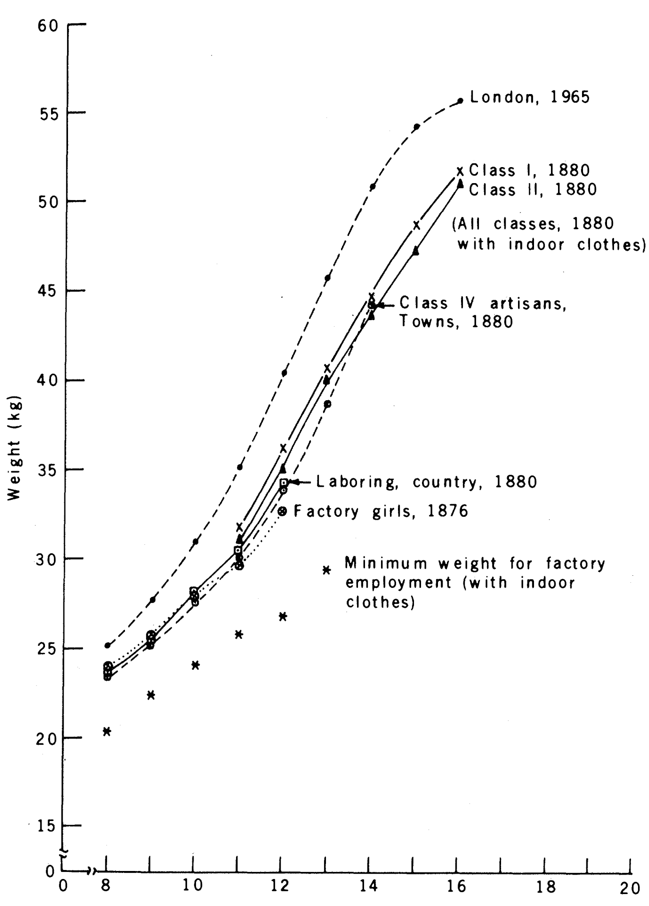
Fresh meat consumption averaged about a pound a week, with greater amounts consumed in the higher wage areas of the North (*60*). Urban workers had less meat than agricultural workers; about 30 percent had no meat in the diet (*60*). Smith advised the urban worker to first buy bread, potatoes, and skimmed milk; then, if money was still available, to buy herrings [which were cheap (*62*)], the cheaper cuts of meat, bacon, and fat (*57*).

The quality of the diet deteriorated in the middle of the 19th century as white patent flour was substituted for whole wheat bread, tea for ale, and jam or a little bacon for cheese (*59*). In Scotland, oatmeal, which was cheap, and usually eaten with milk, making a nutritious diet, also began to be replaced with bread and jam because the working mother did not have time to cook oatmeal. Broth, another Scotch staple, also took too long to cook. The economic development of Scotland was therefore accompanied by a decline in nutrition for the working class (*63*).

Nutrition varied within the working-class family, as well as between classes. The male breadwinner had a better diet than the children, or the wife, who had the worst diet. If meat was available most went to the husband; the wife and children eating the dripping on bread. After 1840 sugar was cheap and treacle became a common spread on bread for children. Children might have bread and treacle twice a day, and perhaps a boiled potato or cabbage smeared with bacon fat. The wife had mainly bread, dripping, and tea. Sunday dinner was the best meal, especially in the towns, where

Table 1. Foods (in grams) consumed weekly by the laboring class in about 1860. Data are for a person over 10 years of age, or two persons below 10 years of age. [From Smith (*57*)] (Pounds and ounces are converted to grams.)

Occupation	Bread, flour, and other farinaceous foods	Sugar or treacle	Butter, dripping, or suet	Bacon or meat	Milk	Cheese	Tea
Agricultural workers in own homes	5594	208	156	454	907	157	14
Silk weavers, kid glovers, stocking weavers, shoemakers	4309	227	142	383	510		21
Needlewomen	3515	206	128	425	199		21



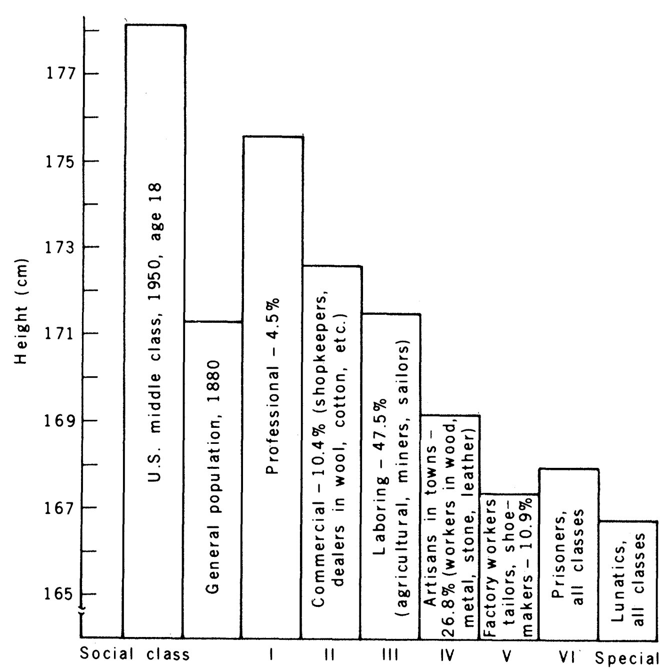


Fig. 4 (left). Body weight by age for British girls of different social classes in 1876 [factory girls (*54*)]; in 1880 [classes I to IV (*52*, p. 293)]; and in 1965 (*82*). The weights for 1876 and 1880 include indoor clothing and clogs or shoes. The minimum weights for factory employment [1876 (*54*)] also included clothes. Height growth by social class shows similar differences (*52*) and differences from modern English girls (*82*). Fig. 5 (right). Height of adult males (without shoes), ages 25 to 30 years, by social class in 1880. [From Galton (*52*, p. 284)] Percentages of population are by class (p. 282). Professional class equals upper- and upper-middle classes, such as gentlemen farmers, officers of army and navy, clergymen, and lawyers; commercial class equals lower-middle classes. The nurture (food, clothing, nursing, domestic surroundings) of class I was very good; II, good; III and IV, imperfect; and V, bad (*52*, p. 282). The height of middle-class U.S. boys at age 18 years in about 1950, height growth completed, is shown for comparison (*20a*).

fried fish, black pudding, or sheeps' trotters were available. In rural areas milk was used freely for tea, but in towns the whole supply of milk per family was only one-fourth to one-half pint daily (*57*). Beer and cider were usually for the head of the family.

Working-class infants were often fed on "sops," (bread, water, and sugar) especially if the mother worked away from home. If a mother could not nurse, and there was no wet nurse, food was sometimes given by bottle with a syphon tube; a "cow's teat" was a nipple. The teat was kept "in gin and water or spirits of wine and water," so careful washing before use was recommended (*57, 64, 65*).

The middle and upper socioeconomic classes in Britain ate more meat and other varied foods, and less bread, than the working class. The adults and older youth ate much as well-off people do today, with perhaps more little meals of bread, butter, and milk. Eggs, vegetables, and meat were included daily in the diet. For example, the daily diet for army officers included meat, vegetable, pudding, bread, butter, milk, and beer (*66*).

Upper-class infants were usually nursed. If a mother could not nurse, a wet nurse who "*was* and *is* well-fed" was recommended (*57*). Upper-class infants were weaned onto milk and other high quality protein foods (*57*).

An important factor in the poor nutrition of the working classes was the lack of facilities for cooking hot foods. Ovens and cast-iron ranges were owned only by the upper classes; even cooking pots were too expensive (*57*) until the invention of the hydraulic press (*60*). Bakers provided hot pies and tarts in addition to bread. Some rural areas lacked fuel for cooking and a hot meal was eaten only once or twice a week (*57*, p. 204). By about 1880 in cities, the pennymeter brought an increase in the use of the gas cooker (*60, 67*).

Smith also gives an estimate of the energy output of a worker: he estimated that a person attending a spinning mill walked or ran 1.3 miles per hour (*57*, p. 224).

The 19th-Century Controversy on the Fall in the Birthrate

These biological facts and views were involved in the controversy at the turn of the century on the reasons for the fall in the birthrate in England (*68–70*). The argument was, as today: does low fertility necessarily imply the use of contraception? Boswell and Samuel Johnson discussed this question at tea in 1769, as quoted by Yule (*68*):

> *Boswell:* Have not nations been more populous at one period than another?
> *Johnson:* Yes, Sir, but that has been owing to the people being less thinned at one period than another, whether by emigration, war, or pestilence, not by their being more or less prolifick. Births at all times bear the same proportion to the same number of people."

"To me this remarkable dictum," continues Mr. Yule, "appears to be contradicted by the experience of every nation for which we have records over a sufficient period of time and of sufficient accuracy."

One of the examples given in detail by Yule is the change in British married fertility by social class and occupation from 1850 to 1900 (*68, 69*). In the middle of the 19th century, data for married fertility did not differ significantly among the social classes or occupations (with the exception of miners who had higher fertility) (*68–70*). Yule implies that the reason the lower classes are similar to the upper classes in having a relatively low fertility is poverty, not the use of contraception (*68, 69*). Yule demonstrates that the fall in fertility which began in England after 1870 did not affect all classes equally: the fall "affected social strata from the top downwards in a rapidly decreasing degree" (*68*, p. 22). Therefore, by the turn of the century fertility differed by social class and occupation (*68–70*). Newsholme and Stevenson concluded that the rich were probably practicing the prevention of childbearing, but among the poor "the practice is almost unknown." Poverty and not "prudential action" was the cause of the relatively low birthrate of the poor. The mass of the population was intermediate in both birthrate and the use of contraceptives (*70*).

Yule's explanation of fluctuations in natural fertility before 1885 was that the birthrate reflected long-term fluctuations of economic determinants (*68*).

The Cost of Contraceptives

The contraceptive devices available before about 1880 were of the ineffective variety, and expensive. An effective male device, a reliable condom, was not available in England until about 1880, when new processes of manufacture, including vulcanization, were used. Effective female devices, diaphrams and pessaries, also became available with the advances in rubber manufacture (*65, 71*). The cost of these devices, however, make it improbable that they were used by the working classes. Condoms cost 2 to 10 shillings a dozen; rubber pessaries from 2 to 5 shillings each (*65*). The staple of the diet, a four-pound loaf of bread, cost about 7 pence (*72*, p. 168).

Less effective methods were equally expensive, relative to the cost of bread. The contraceptive sponge, recommended by Besant in her *Law of Population* (*43, 73*) cost 1 shilling each. Soluble quinine pessaries cost 2 shillings a dozen in about 1890 (*65, 74*).

Summary and Conclusions

Although the historical data are necessarily incomplete and imperfect, these data support the hypothesis that a short and less efficient reproductive span due to poor nutrition, hard physical work, and poor living conditions may be an explanation of the relatively small completed family size of the lower socioeconomic classes in about 1850 to 1860 in Britain.

The relatively late age of menarche and late attainment of adult height of even upper-class girls and boys compared to contemporary well-fed children (*52*) suggests that some submaximum fecundity, in combination with a late age of marriage may have also contributed to the small completed family size of the upper classes in 1850. A late age of marriage would have placed most of the childbearing years in the period of declining female and male fecundity. The historical decrease of fecundity with age was more rapid because of the partial subfecundity (Figs. 1 and 3).

One cannot disprove the use of coitus interruptus as the explanation of the observed lower fertility of both the lower and upper classes. However, the physical and reproductive data provide an alternative explanation, wholly or in part, especially for the lower socioeconomic classes (*75*).

If subfecundity contributed to low fertility among the poor families in Britain in about 1850, a rise in fertility due to better food and living conditions may have preceded the fall of the birthrate at the end of the 19th century (*67–70, 75*).

Undernutrition, instead of the widespread use of folk contraception, may also be the explanation of the completed family size of six to seven children found in many developing countries today, as has already been suggested (*5, 19, 27, 75*). If so, the nutrition programs necessary for a vigorous, productive society should be closely integrated with family planning programs for the well-being of the mother, the child, and the society (*19, 27*). The need for family planning programs also may be much greater than realized heretofore.

If subfecundity is the main reason for the relatively low observed fertility in the 19th century, a reasonable question is: who was using the many (inefficient) methods of contraception devised during human history? (*71*). The data suggest that only females (and males) who were well nourished, and hence fully fecund, whose reproductive ability exceeded their aspirations for offspring, would have used contraception. This would be a small percentage of the population: the relatively well-fed aristocracy [Peel's elite (*65*)], especially when they used wet nurses (*76*); the wet nurses themselves, since pregnancy would affect their ability to nurse (*76*), and prostitutes, whose aspirations of fertility were zero.

Finally, the 19th-century data raise some fundamental biological questions. The fact that undernourished human beings and animals are less fecund than well-nourished populations can be regarded as an ecological adaptation to reduced food supplies of the environment, and as being of obvious advantage to the population. It is a less wasteful mechanism than the regulation of overpopulation by mortality. But, by what mechanism is a slower rate of growth of females and males within a population related to a subsequent shorter and less efficient reproductive span? Why is a late menarche in a population usually associated with an earlier menopause; with long lactation intervals, and with higher pregnancy wastage (*27*)? Are there exceptions in some environments to these associated events? How much is reversible after growth is completed?

Recent experiments with rats fed on high-fat and low-fat diets suggest that the estrogen levels were higher in the rats on high-fat diets (*77*). The well-nourished human female and male, particularly on diets with a high percentage of calories from fat, also may have higher endocrine levels, which result in a high reproductive efficiency (*78*).

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83. The historical research was supported by Population Council grant D74.94C. General biological aspects were part of research done while a Fellow of the John Simon Guggenheim Memorial Foundation (1975–1976). I thank R. J. Wolfe, Rare Books Librarian in the Francis A. Countway Library of Medicine, Harvard Medical School, for generous advice and assistance with source materials; J. Singer for compilation of food intake and growth data; and J. Lambertz for assistance with the bibliography.

NEWS AND COMMENT

Gene-Splicing Rules: Another Round of Debate

Most biologists concerned with recombinant DNA consider that modest relaxations would now be justified in the National Institutes of Health rules governing the research.

But the agency has come under serious criticism for the way in which it has gone about revising its rules. At a public meeting held at the NIH campus on 15–16 December, Washington attorney Peter B. Hutt lectured the NIH for proposing the revisions with "undue, unnecessary and unseemly haste." Another attorney, Georgetown University law professor Patricia King, told the NIH that she was "terribly upset by the procedure for making the revisions."

Hutt's criticisms are significant because, as former general counsel for the Food and Drug Administration, he has acquired particular expertise in the regulation of biomedical issues. He is also a warm admirer of the scientific content of the NIH guidelines and of scientists' initiative in framing them.

At the NIH meeting, Hutt criticized not only the procedural basis of the present revisions but NIH's legislative and political strategy for handling the recombinant DNA issue over the last 2 years. He believes that instead of listening to those who didn't want to be regulated, the NIH should have followed the advice he gave in February 1976 to maintain the initiative and use already existing legislative authority to regulate gene-splicing research. "When NIH and HEW decline to use their legislative authority, they invite others to step into a regulatory void," Hutt opines. He regards the recent bills introduced in Congress as "the worst form of over-reaction" and Senator Kennedy's in particular as "an utter atrocity."

The authority which Hutt urged the NIH to use in 1976 is a statute which gives the Surgeon General sweeping power to control communicable diseases (*Science*, 27 February 1976). At last month's meeting Hutt said he had checked with other government attorneys and still felt strongly that the statute "provides ample legal authority." NIH director Donald Fredrickson, however, says the legal advice he has always received is that the statute is insufficient and that attempts to use it would be challenged in the courts. The Pharmaceutical Manufacturers Association has advised the NIH that it would accept the statute, even though it would have to be "stretched" a little, as a basis for regulating industry.

The purpose of last month's meeting was to consider the guideline revisions prepared by the NIH recombinant DNA advisory committee in May and June 1977. The revisions, which constitute generally minor relaxations of the present guidelines, are chiefly inspired by the realization that *Escherichia coli* K12, the standard bacterium used to propagate recombinant DNA molecules, is a much safer host than was originally believed. A principal fear at the time the guidelines

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