Energy costs of a long life

SIR — The publication in 1989 of a stamp commemorating the centenary of the German social security system (see figure) has, probably inadvertently, focused attention on the widely neglected phenomenon of the virtual doubling of the average life expectancy in advanced industrial societies over the past 100 years. Whereas the age distribution of agrarian or early industrial societies displays the shape of a pyramid typical of most biological populations (left-hand graph), the demographic picture of developed communities is reflected by a balloon-shaped function, the narrow base of which constitutes an artefact caused by the introduction of oral contraceptives during the 1960s (middle and right-hand graphs in the stamp).

Although many will ascribe this demographic miracle to a multitude of specific causes (notably the advances of biomedical sciences during the past century), the root cause deserves to be stated explicitly. The principal factors promoting longevity in humans (balanced nutrition, evasion of excessive toil, provision of medical care, social security and so on) are corollaries of developed societies characterized by sizeable gross national products (GNP). Because of the well-established correlation between GNP and energy consumption, it seems evident that the conspicuous doubling of the average life-span of whole populations (not of a minority) over the past 100 years is linked to the progressively increasing energy flow through society over the same time. Biological analogues demonstrate that similarly conspicuous innovations had been generally dependent on preceding discrete quantum steps in bioenergetic evolution involving upsurges in physiological energy consumption by about an order of magnitude and more[1]. This is approximately the factor by which the industrial ('extrasomatic') energy flux surpasses the per capita somatic flux in modern industrial societies (for instance, the 1.6-million population of the city of Hamburg has a physiological energy consumption of some 5,000 TJ yr^{-1}, whereas the energy expenditure of the community as a whole totals 100,000 TJ yr^{-1}.

A glaring demonstration of the interrelationship between the energy-related GNP and life expectancy has been furnished by the temporarily diverging socio-economic orders of former East and West Germany, with average life spans cut by 2.5 and 7 years for men and women, respectively, from the East[2]. Specifically as a result of this historical experiment, it is clear that average life expectancy for broadly the same human gene pool is apt to vary significantly in response to the socio-economic environment, with a conspicuous advantage for the more voracious energy consumers.

With these interrelationships established, it is not difficult to predict that there will be no voluntary way back from a high-energy to a low-energy economy. Naive criticism of modern industrial society ignores the privileged condition of its members in terms of both life expectancy and general diffusion of affluence, disregarding the fact that the recent rise of energy consumption by *Homo sapiens* to levels 10–20 times above the basic metabolic rate is glaringly beneficial to the species.

The 1989 stamp compares age composition of an agrarian/early industrial society (1889) to that of an advanced industrial society (1989 and projection for 2000). Note that the population 'pyramid' typical of poorly developed (low-energy) societies assumes the shape of an elongated balloon for high-energy societies (in these examples, this shape is gravely impaired by scars left by two major wars).

Although the increased energy flow through the human ecosystem is evidently responsible for this most important single improvement of the human condition in the history of mankind, its intrinsic potential for the emergence of an autotoxic (self-poisoning) effect due to the accumulation of toxic waste products of the industrial process remains a matter of concern[3]. The future of high-energy (industrial) societies will, accordingly, depend on man's capability to maintain an adequate energy flow while minimizing the adverse effects of his extrasomatic metabolism on the environment by suitable technological fixes[4].

MANFRED SCHIDLOWSKI

Max-Planck-Institut für Chemie,
Postfach 3060,
6500 Mainz,
Germany

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Smart whale

SIR — Daedalus (*Nature* **352**, 384; 1991) described a novel 'heavy-waterglider' whose undulating trajectory derives from the depth-related changes in density that follow from the unusual thermal properties of heavy water. Fact is even better than fantasy, for his design has been largely pre-empted by the sperm whale. The substitution of spermaceti oil for heavy water, and the closer control of heating and cooling by changes in the internal blood supply, make the sperm whale a much more flexible undulator[1]. It also has an operationally tried and tested 'smart' navigation system, instead of an automatic one. Its celestial navigation system is still classified information, the details of which are transferred only on a 'need to know' basis for regular migrations. Daedalus's vehicle "will be guided to rendezvous . . . by sonar steering commands". The sperm whale's mastery of the language of sonar completely outclasses its vehicular competitor, but the rendezvous of its choice is more likley to be a mate or a family party that Daedalus's "receiving tug".

As part of the promotional strategy for the vehicle, Daedalus asserts that "oceanographers will love the heavy waterglider". He should know that we already do love the sperm whale.

PETER J. HERRING

Institute of Oceanographic Sciences,
Deacon Laboratory,
Brook Road,
Wormley,
Godalming,
Surrey GU8 5UB, UK

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Grand spectacles

SIR — As a sufferer from presbyopia, I have longed for the 'adaptive optics' spectacles proposed by David Jones (Daedalus, *Nature* **352**, 287; 1991). I have two suggestions for improvements.

First, the eye has significant chromatic aberration, so the infrared image will have to be slightly out of focus in order to focus the optical image perfectly. Second, I wish to retain what focusing ability I still have for occasions when I do not use my spectacles. I suggest therefore a bias and lag in the automatic adjustment, calculated to excercise my eye muscles so that they do not atrophy. Both effects would be simple for the microprocessor controlling the optics.

NELSON MAX

Lawrence Livermore National Laboratory,
Post Office Box 808,
Livermore,
California 94550, USA

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