bipeds, including man and seven species of birds. The slope of the line for birds (−0.20), however, is only half as great as that for quadrupeds. The line for this relation in penguins has a slope of −0.33. The values of E for penguins are higher than would be expected for other birds or quadrupeds (Table 1).

Penguins and geese have an "awkward" gait when they walk, which we call waddling; their bodies undergo large lateral displacements. In emperor penguins the lateral and rotational movements of the trunk are large enough to cause the tail to draw a sinusoidal track in the snow. Penguins and geese have legs that are relatively short compared to those of guinea fowl, turkeys, and rheas, and their range of walking speeds is comparatively limited.

Mechanical analysis may explain why E and M_t are higher in waddling birds than in running birds. Waddling may involve large kinetic energy changes with each stride, and short legs require a higher stride frequency to walk at a given speed than do long legs. Stride frequency of emperor penguins walking at the maximum speed they can maintain (2.8 km $hour^{-1}$) is about 85 strides per minute (*13*). Stride frequency of a rhea at the same speed is 50 strides per minute, or only 60 percent of that of the emperors. When stride frequency of Adélie penguins is compared to that of turkeys, the difference is even greater. At 3.9 km $hour^{-1}$, the stride frequency of turkeys is only 50 percent of that of the Adélies. The speeds used for this comparison are the top speeds that the two species of penguin would maintain on our treadmill, but both turkeys and rheas can move much faster.

The morphology of penguins and geese may in part represent a compromise between aquatic and terrestrial locomotion. Both energy economy and speed of walking seem to suffer as a consequence.

A low walking speed probably is not a detriment to the antarctic penguins, for they have no terrestrial predators. If need be, they can travel faster by tobogganing on their bellies; this allows them to use their powerful flippers to push themselves along on the snow. In emperor penguins, however, the high energy cost of walking could have serious effects on breeding success during seasons when rookeries are separated from the sea by unusually broad sea ice (*7*).

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Selenium in the Environment

The role of methylation of selenium in the aquatic environment, as discussed by Chau *et al.* (*1*), adds to knowledge of the Se cycle in nature. Their statement, however, that Se and its compounds are carcinogens and environmental pollutants calls for correction. Evidence that Se is not a carcinogen has been summarized by many (*2*). Evidence has accumulated to indicate that the ambient unavailability of Se for uptake by plants in some areas actually increases susceptibility to cancer (*3*). The incidence of some forms of cancer appears inversely related to levels of Se in human blood, milk, and locally grown plants (*3, 4*).

As prosthetic group of the oxidoreductase glutathione peroxidase (*5*), Se functions with vitamin E in the avoidance of aberrant oxidations of lipids. Nutritional inadequacy of Se is thought to underlie various chronic diseases caused by such aberrant lipid oxidations (*6*), including cardiovascular disease (*6, 7*). The absolute essentiality of Se for animals is well established (*2*) and its essentiality for humans strongly indicated (*8*). Selenium deficiency is thought to represent far more of a problem than are any likely excesses of Se in the environment. Realistically, then, Se should be viewed not as a pollutant, but as a critically essential nutrient.

The incidence of Se-responsive diseases in livestock and even in zoo animals has increased steadily for two decades. The concept that nutrient inadequacy is a growing problem due in part to imbalance between the sulfur and selenium cycles was advanced (*6, 9*). If the availability of Se in the air-soil-plant-animal-human food chain is diminishing, what it may mean in terms of human nutrition can only be speculated upon. In any case, evidence suffices to invoke critical investigations of the possible anticancer value of Se, as well as its reported value against other chronic diseases.

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The carcinogenicity of selenium is indeed highly controversial. While we do not wish to engage in discussing this controversy, we wish to comment on Frost's statement that "Se should be viewed not as a pollutant, but as a critically essential nutrient."

Although Se has been recognized as an essential element for some animals and bacteria, its functions as a micronutrient for humans are still uncertain (*1*). Many cases of acute and chronic toxic effects of Se on humans are known (*1, 2*). Some of these effects were caused by high concentrations of Se in drinking water. Selenium has been suggested as one of the dangerous chemicals reaching the aquatic environment (*3*). Its toxicity has been demonstrated in goldfish and catfish (*4*). A concentration of Se in water as low as 0.25 mg/liter can cause a significant behavior impairment in the goldfish (*5*). Physiological and morphological changes have also been observed in algae exposed to $10^{-6}M$ Se (*6*). Because of its low safety factor [defined as the ratio of the toxic rate to the normal ingestion rate (*7*)], which is 25 for Se compared to 50 to 500 for As and 500 to 2000 for Hg, and its bioaccumulation by zooplankton in Lake Michigan, Se is considered as a potential hazard to the environment (*8*).

As environmental scientists ourselves, we are more concerned with the abundance, accumulation, and impact of Se in the environment and in the food chain. Whether an element is or is not viewed as a pollutant has little to do with its nutritional values. For example, both phosphorus and nitrogen are very essential nutrients; the fact that their abundance in natural waters causes water eutrophication classifies them as typical environmental pollutants.

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Negative Energy Impact of Modern Rail Transit Systems

It has always seemed obvious that substantial energy savings could be achieved by diverting commuters from automobiles onto rail transit. In fact, the wisdom of this idea has appeared so self-evident, to so many people, that it has been little examined. In the only direct analysis of this problem (*1*), Bezdek and Hannon calculated the energy cost of various kinds of transit construction and concluded that the United States could save energy by diverting investment from highways to rail transit. This conclusion was based on a theoretical analysis of the problem, but if one analyzes actual cases, standardizing by some measure of the services produced (passenger-miles of travel) one finds a totally opposite result. In my analysis I have used data from the San Francisco Bay Area Rapid Transit (BART) system, and here I present evidence to show that BART is typical of other modern rail systems.

Both rail transit and highways require a substantial investment of energy in their construction, and both are intended to produce passenger-miles of travel as the payoff to this investment. Hence the criterion of passenger-miles per British thermal unit (PM/Btu) seems a reasonable way to evaluate their relative efficiencies.

The BART system carries 130,000 passengers per commuting day, with an average trip length of 13.0 miles (*2*) and hence its output is 4.39×10^8 PM per year. It cost $2.28 billion (in 1974 dollars) to build (*2*, p. 163) and, by using an energy conversion ratio of 7.76×10^4 Btu per dollar (*3*), the total energy invested in BART can be calculated as 17.7×10^{13} Btu.

An urban freeway carries 18,000 daily cars per lane-mile, with an average of 1.4 passengers per car (*4*), if it is located in a travel corridor with enough traffic to justify rail transit. Thus it would take 67.1 lane-miles of freeway to carry BART's passengers. With a construction cost of $932,000 per lane-mile, and an energy conversion ratio of 11.2×10^4 Btu per dollar for highway construction (*5*), this works out to a total energy investment of 0.701×10^{13} Btu.

If one compares the construction energy invested in BART to the energy required to construct an urban freeway with the same capacity, it is evident that BART used 25.2 times as much energy. Alternatively stated, freeway construction produces 25.2 times more PM/Btu than rail transit construction.

I chose BART because it is the only operational, complete, new-generation rail system, and hence has measured data rather than engineering projections. This is important: BART cost twice as much, carries only half as many passengers, and uses double the propulsion energy as was forecast (*2*).

The result calculated above is primarily sensitive to two parameters, the high construction cost of rail systems, and their relatively low degree of use. If one takes these two parameters in turn: BART cost $32.1 million per system mile; the projected cost for three other rail systems now under construction is $34.4 million per system mile (*2*, p. 163). Hence, if BART is at all atypical on this criterion, it is atypically efficient. Total patronage is harder to compare since none of the other new systems has yet been proved. There is, however, good reason to believe that the others will do no better than BART: the average proportion of work trips, via bus and rail transit, across Boston, Chicago, Cleveland, Philadelphia, and Washington is 18.8 percent; in San Francisco this proportion is 25.1 percent (*6*). The unusually high proportion of work trips made via transit systems and the relatively high-volume traffic corridors caused by the geographic constraints of the Bay Area combine to make BART's patronage higher than might be experienced in other cities. Hence, again, if BART is atypical, it is atypical in a way favorable to BART's efficiency.

Because BART attracts passengers from buses and cars, there will be fewer vehicles on the highway, and hence less

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