predict how changes in climate parameters such as maximum and minimum temperatures and the spatial and temporal patterns of precipitation affect the distribution of major vegetation types across the globe (*5*). Using these models with scenarios of future climate change, researchers have identified many potential consequences of large-scale vegetation shifts. The composition of one-third of Earth's forest could change markedly as a result of climate changes associated with a doubling of atmospheric CO_2. Over the next 100 years, the ideal range for some North American forest species could shift as much as 300 miles to the north. Economically and aesthetically important species, such as the sugar maple, could be lost from New England by the end of the next century (*6*).

One of the most robust predictions of the new dynamic global vegetation models is that by 2100, boreal forest will occupy a substantial portion of the land that is now covered by tundra vegetation. Because boreal forests absorb much more solar radiation than tundra does, poleward shifts in the location of the forest-tundra boundary during a period of warming can amplify climate changes by as much as 50% (*7*).

Researchers are using three main approaches for investigating the consequences of climate change on natural ecosystems. Through long-term observations, including those taken from the paleorecord, scientists have begun to detect some of the effects of warming on the structure and function of natural ecosystems. Through experimental manipulations of the environment and the use of ecological simulation models, scientists are gaining insights into possible future consequences of warming and other aspects of climate change for our life support system, the biosphere. These three approaches—observation, experimental manipulation, and simulation modeling—are complimentary and are all needed to improve our understanding of the consequences of climate change for Earth's life support system, the biosphere.

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PERSPECTIVES: HUMAN PHYSIOLOGY

Beyond Sloth—Physical Activity and Weight Gain

Eric Ravussin and Elliot Danforth Jr.

Obesity is not sought. It appears uninvited and is epidemic in modernized societies in which overconsumption of food is promoted and physical activity discouraged (*1*). Gluttony and sloth are frequently blamed, but in fact it is not clear why some of us in this environment become obese (despite considerable effort not to) while others, without such effort, do not. It has been difficult to accurately solve the energy balance equation in people to determine whether differences in energy expenditure explain these differences in obesity. Now Levine *et al.* (*2*) on page 212 of this issue offer evidence that the best predictor of interindividual differences in fat gain during overeating is the amount of certain physical activity triggered by the excess food. More specifically, this physical activity consists of movements during daily living, termed nonexercise activity thermogenesis, or NEAT.

The acronym NEAT encompasses, besides the energy costs of activities of daily living, the energy costs of all nonvolitional muscle activity such as fidgeting, muscle tone, and maintenance of posture when not lying down—essentially all physical activity not picked up by a pedometer.

Although humans have evolved thrifty mechanisms to defend energy stores during times of privation, they cannot easily prevent storage of energy when food is abundant. The survival mechanisms that evolved during times of famine, which Neel (*3*) referred to as the "thrifty genotype," becomes a liability for some during times of feast. At the turn of the century Neumann (*4*) from studies on himself, was the first to suggest that the consequences of overeating were not always reflected in the weight gained, referring to it as "luxuskonsumption." "Easy" and "hard gainers" (of weight) were uncovered in response to purposeful overfeeding by Sims *et al.* (*5*), and resistance to change in body energy stores was recently documented by Leibel *et al.* (*6*). Bouchard *et al.* (*7*), in studies of identical twins, established that the ease of weight gain is influenced by genes. The responsible mechanisms, however, have remained elusive.

Selective breeding of rodents, cattle, pigs, and chickens have uncovered breeds with variable energy efficiencies during growth, and variable energy requirements for maintenance of adult weight (*8*). Overfeeding activates the sympathetic nervous system, resulting in increased thermogenesis in brown fat through uncoupling of oxidative phosphorylation. Such a mechanism wastes energy as heat and is similar to what is observed during exposure to cold in small animals and human infants (*9*). Whether some humans may be hard gainers because of their greater retention from birth of active brown fat remains to be established.

The energy expenditure upon overfeeding can be divided into several components (see the figure). After overfeeding, the resting metabolic rate—popularized by Boothby for the diagnosis of thyroid disorders (*10*)—increased modestly, accounting on average for 8% of the excess calories consumed. The increase in the thermic effect of food (the cost of absorbing and storing the ingested calories) was only proportional to the increase in the ingested calories, accounting for 14% of the daily excess. Similarly to resting metabolic rate, the increase in the thermic effect of food could not account for the differences between individuals. So what did account for the interindividual variability in gain in body fat? The authors concluded that it must be the remaining way that energy is expended—in physical activities, volitional or otherwise.

As pointed out by the authors and suggested years ago by Widdowson (*11*), the fidgetiness of an individual likely plays a more important role in daily energy expenditure than previously thought. Within the confines of a respiratory chamber spontaneous physical activity (fidgeting) accounted for an average of 348 kcal/day (*12*). More important, it is a major cause of individual differences in 24-hour energy expenditure (100 to 700 kcal/day) and is a predictor of gain in weight (*13*).

In the present study, the energy cost of physical activity was carefully apportioned between voluntary exercise (such as walking and running) and nonvoluntary exercise (NEAT). Accomplishing this is a "tour de force" in the use of state-of-the-art modern techniques for assessing energy metabolism and body composition in humans. The key was the use of the dou-

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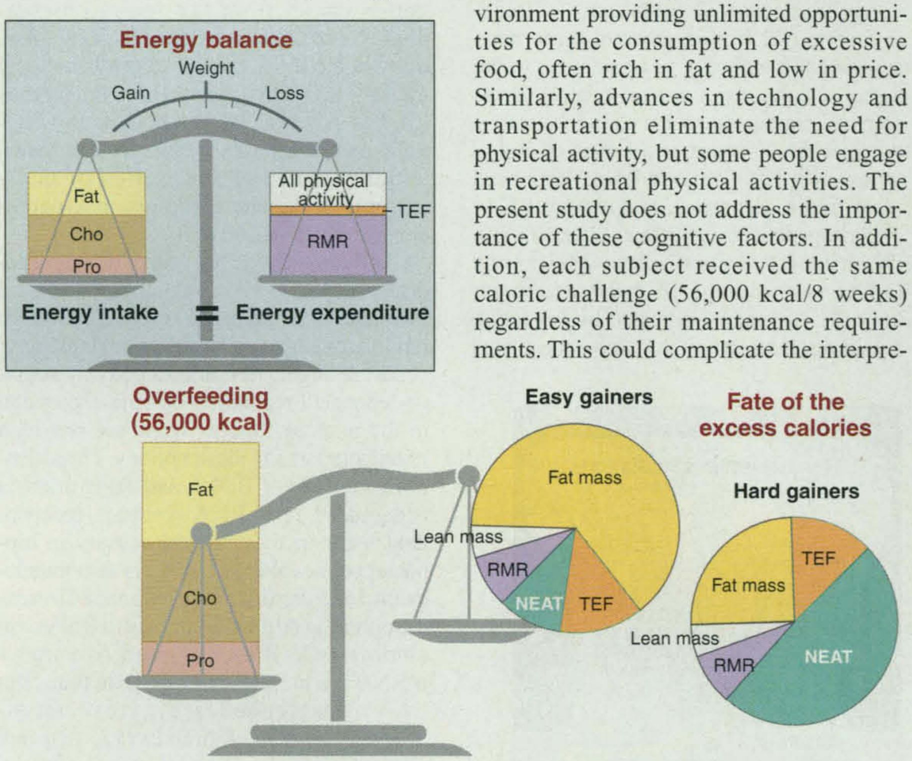
E. Ravussin is at Eli Lilly and Company, Indianapolis, IN 46285, USA. E-mail: eric_ravussin@lilly.com. E. Danforth Jr. is at the University of Vermont, 05405, USA. E-mail: ravussin_eric@lilly.com

bly labeled water to estimate total energy expenditure in unrestrained individuals and dual x-ray absorptiometry to determine body composition in conjunction with close monitoring of food intake and volitional exercise. The energy cost of muscular activity was determined by the difference between total daily energy expenditure and the energy expended for resting metabolism and the thermic effect of food, both measured by indirect calorimetry. By imposing a constant amount of volitional exercise over the period of study, assessed by pedometer, the energy expended for other pursuits, usually impossible to measure, could be deduced. Combined with a precise determination of body composition and the assumed energy content of the weight gained, the fate of all of the overfed calories could be determined (see the figure). The other pursuits or NEAT accounted for the largest variability in the amount of fat gained in the 16 subjects.



Watching your weight. (Top) When energy intake exceeds energy expenditure, weight is gained, with most of the extra energy stored as body fat and smaller amounts as lean tissue (protein and glycogen). When energy expenditure exceeds intake, weight is lost, with most of the loss of energy as body fat and smaller amounts of lean tissue. Physical activity can be divided into the energy used for conscious activities (mostly volitional) and for NEAT or nonexercise activity thermogenesis. The bottom panel summarizes the results in (*2*). In response to overfeeding, an average 39% of the excess calories were stored in the body as fat and 4% as lean tissue (protein and glycogen). The remaining excess calories were dissipated by thermogenic mechanisms [8% in RMR; 14% in TEF (proportional to the increased intake); and 33% in physical activity, both volitional and nonvolitional (defined by the authors as NEAT)]. Most of the increase in physical activity was accounted for by an increase in NEAT because volitional activity was kept constant. The variability in the gain of fat was inversely related to the subjects' ability to increase NEAT. RMR, resting metabolic rate; TEF, the thermic effect of food (energy required to absorb and store the ingested calories).

By design, both food intake and volitional physical activity were kept constant. However, in real life some people resist gain in weight by restrained eating and purposeful exercise. Cognitive factors can avert overindulgence in spite of an environment providing unlimited opportunities for the consumption of excessive food, often rich in fat and low in price. Similarly, advances in technology and transportation eliminate the need for physical activity, but some people engage in recreational physical activities. The present study does not address the importance of these cognitive factors. In addition, each subject received the same caloric challenge (56,000 kcal/8 weeks) regardless of their maintenance requirements. This could complicate the interpretation, because the caloric challenge was relatively smaller for a 92-kg male than a 53-kg female. In addition, self-reported activity and pedometer counts may not be sensitive enough to reliably predict physical activity over long periods of time. Indeed, although the average pedometer scores were unchanged, individual differences between baseline and overfeeding varied as much as 30%. Although exercise efficiency was unaffected by overfeeding, the cost of carrying around the added weight may have required more energy expenditure. Others using similar techniques have not found changes in activity related energy expenditure after shorter periods (21 days) of overfeeding (*14*). In this case, the 3 weeks of overfeeding was perhaps not sufficient to induce wasteful mechanisms of energy expenditure such as NEAT. Alternatively, the variability in the magnitude of overfeeding was large enough to leave undiscovered the variability in NEAT. Nevertheless, this carefully conducted study provides an interesting explanation for the differences in gain of body fat in response to overeating. Whether the amount of energy used in NEAT explains why some but not all of us become obese in an affluent environment remains to be determined.

Why are some of us fidgety or restless when overfed whereas others remain phlegmatic in our daily activities? Is an increase in NEAT induced by overindulgence an innate behavior? Certainly it must have been a surprise to the authors that overfeeding should increase nonvolitional physical activity, because overeating is usually thought to produce inactivity or, at least, greater dormancy. What determines the amount of energy we expend that does not show on our pedometer? Do some people use more muscle tone than others to maintain posture? Are we talking about A and B personality types, or were the hard gainers restless sleepers, or did the easy gainers simply sleep more than the hard gainers? A study by Christin *et al.* (*15*) offers intriguing evidence that interindividual variability in sympathetic nervous system activity may determine the need to fidget or not. Such a mechanism could explain why some of us escaped gaining weight, whereas others did not, after overindulging during the past holiday season. The winners in the battle of the bulge in our present "obesigenic" environment were losers during the famines of early humankind. Today, however, it would be neat to understand why some of us have more NEAT than others.

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