in an effort to lose weight, your metabolic rate will decline and your cholesterol level will climb. Rapid weight gain may follow your temporary weight loss.

Fitness and Fat

The effects of activity on weight control and energy balance are well established. Systematic and progressive exercise leads to improvement in aerobic fitness. This section deals with the extra benefits associated with improved fitness, benefits that provide dramatic evidence of the role that fitness plays in health and prevention of heart disease. These benefits include the following:

- Increased caloric expenditure
- Increased fat mobilization
- Increased fat utilization
- Reduced blood lipids
- Increased lean tissue (muscle)

Caloric Expenditure

Because unfit people tire quickly during exercise, they have limited ability to expend calories. As fitness improves, caloric expenditure rises, with increases in the intensity, duration, and frequency of exercise and because of the inevitable participation in activities that are more vigorous. The fit person does more with less fatigue. Increased fitness undoubtedly contributes to energy expenditure and weight control.

We have studied the effects of training on individuals’ perception of effort and fatigue (Docktor and Sharkey 1971), and recent studies confirm the beneficial effects of training on one’s perception of effort (Gaskill et al. 2005). As fitness improves, a person can perform more work at the same heart rate and level of perceived exertion. Work levels once perceived as difficult become less so, and once-fatiguing exertion can be managed with ease. After training, a person can accomplish a given task with a lower heart rate as well as a lower level of perceived exertion. Thus the subjects are able to burn more energy without experiencing a greater sense of fatigue.

Further proof of the value of fitness to caloric expenditure is found in the relationship of caloric expenditure to heart rate. Caloric expenditure is related directly to heart rate, but level of fitness also influences the relationship. For people in low fitness categories, a high heart rate does not indicate extremely high caloric expenditure (see figure 13.1). For those in high fitness categories, the same heart rate (HR) indicates much higher energy expenditure:

- 140 HR for very poor fitness level = 6 to 7 calories per minute expended
- 140 HR for very good fitness level = 12 calories per minute expended

You can use figure 13.1 to estimate your caloric expenditure in any activity. After several minutes of participation, stop and immediately take your pulse at wrist or throat (use gentle contact) for 15 seconds. Multiply by four to get your rate per minute. Then use the line corresponding to your fitness level to estimate your caloric expenditure.
per minute. Notice how caloric expenditure will improve (at the same heart rate) as your fitness improves. This finding should convince you that fitness provides extra benefits to those who persevere.

**Fat Mobilization**

Fat is stored in fat cells in the form of triglycerides (three molecules of fatty acid and one molecule of glycerol). A triglyceride molecule is too large to pass through the wall of the fat cell into the circulation, so when energy is needed, the triglyceride is broken down and the fatty acid molecules pass into the blood for transport to the working muscles. The hormone epinephrine stimulates a receptor in the fat cell membrane and activates the enzyme lipase. Lipase splits the triglyceride molecule, and the fatty acids are free to enter the circulation.

As exercise becomes more intense, we produce lactic acid. The point at which lactic acid begins to accumulate in the blood, the second lactate threshold, indicates when lactate production exceeds removal. At this intensity a significant shift from fat to carbohydrate metabolism has occurred. You will recall that the second lactate threshold is related to activity and fitness. It may be below 50 percent of the maximal oxygen uptake for the unfit and above 80 percent for the highly trained. But what does that have to do with fat?
Years ago, researchers discovered that lactic acid seemed to inhibit the mobilization of free fatty acids (FFAs) from adipose tissue (see figure 5.5, page 94). The lactic acid blocked the action of epinephrine, thereby reducing the availability of fat for muscle metabolism (Issekutz and Miller 1962). One of the best-documented effects of training is that more work can be accomplished before lactic acid levels rise. After improving fitness, a person who formerly produced lactic acid at a given workload can accomplish the same workload with little increase in lactic acid. This result may be because of a decrease in lactic acid production or an increase in lactic acid clearance. Whatever the case, improved aerobic fitness allows a person to accomplish more work aerobically. The lactate threshold increases, and more fat is available for use as an energy source.

A study of trained subjects illustrates that moderate levels of lactic acid do not affect FFA mobilization and utilization (Vega dejesus and Siconolfi 1988). The fit subjects were able to mobilize fat at the second lactate threshold (4 millimoles lactic acid), which defines the highest level of exercise intensity that a person can sustain during prolonged exertion. These findings help explain the tremendous increase in endurance associated with training. Fat is the most abundant energy source (50 times more abundant than carbohydrate). Improved fitness allows greater access to that immense storehouse of energy.
Lactic Acid

Lactic acid is produced when the breakdown of muscle glycogen (to three carbon pyruvic acid molecules) exceeds the ability of the mitochondria to process this metabolite. So the pyruvic acid picks up hydrogen, becomes lactic acid, and begins to accumulate in the muscle and blood. The heart and skeletal muscle can use lactate as a source of energy, and the liver can oxidize it. But when production of lactate exceeds removal, the level in muscle and blood increases. The rising level of acid in the muscle reduces force production by interfering with muscle contractions and decreases endurance by lowering the efficiency of aerobic enzymes.

Fat Utilization

The mobilization of fat does not ensure its metabolism. How does training influence the utilization of FFA as a source of energy for muscular contractions? Studies have shown that trained animals and humans are capable of extracting a greater percentage of their energy from FFA during submaximal exercise. How, then, does fitness influence fat utilization?

Lipoprotein Lipase

Earlier we talked about LPL in adipose tissue. In muscle the LPL helps grab circulating fat from the blood and use it for energy. Muscle LPL activity increases with endurance training and enhances the ability of the muscle to use fat as a fuel (Nikkila et al. 1978).

Fat Oxidation

Móle, Oscai, and Holloszy (1971) provided convincing proof of the effect of training on FFA utilization. They found that the ability of rat muscle to oxidize the fatty acid palmitate doubled following 12 weeks of treadmill training. The authors suggested that the shift to fat metabolism was a key factor in the development of endurance fitness and an important mechanism serving to spare carbohydrate stores and prevent low blood sugar during prolonged exertion. Thus the physically fit person is able to derive a greater percentage of energy requirements from fat than the unfit subject can. At a given workload, the fit subject may obtain as much as 90 percent of his or her energy from fat. Free fatty acids are used during all forms of muscular activity, except for all-out bursts of effort such as the 100-yard (100-meter) dash. Training even seems to improve the ability of the heart muscle to oxidize fat (Keul 1971).

When exercise begins, the initial source of energy from fat is from intramuscular fat, a supply that is enhanced with training. When prolonged activity depletes intramuscular fat, the body uses fat that comes from adipose tissue by way of the blood (Coggan and Williams 1995). Improved fitness increases the availability of fat through mobilization of FFAs, as well as an increase in enzyme activity. Both contribute to the rate of FFA utilization.