CHAPTER 1

WHAT IS PERFORMANCE NUTRITION?

Doping in sports has been big news in recent years. The use of illegal performance-enhancing drugs and of other banned measures such as blood doping has reached crisis proportions. While the sports of baseball, football, cycling, and track & field have been hit the hardest, long-distance running has been hit, too.

One of the most dramatic blows fell in 2000, when former 5000-meter world record holder Dong Yanmei and six other Chinese runners were cut from the Chinese Olympic Team after testing positive for use of synthetic EPO (short for erythropoietin, a blood-boosting hormone). The following year, closer to home, Regina Jacobs, the 5000-meter American record holder, tested positive for the synthetic steroid THG. And the year after that, Brahim Boulami of Morocco, world record holder in the 3000-meter steeplechase, was banned from the sport for 2 years for using EPO.

In this same period of time, I became involved in an advocacy group called Powering Muscles that sought to address the problem of doping in sports. An initiative of the United States Track Coaches

Association, Powering Muscles was a multidisciplinary educational effort involving exercise physiologists, nutritionists, track coaches, and athletes that was designed to teach other track coaches, trainers, and athletes about the role of nutrition in athletic performance. Our overarching goal was to reduce athletes' use of performance-enhancing drugs by demonstrating that nutrition offers a safer and equally effective alternative.

Most runners believe (or at least assume) that no legitimate alternative can match the performance-boosting effects of a drug such as EPO. It's probably true that no *single* legitimate alternative to doping can do so, but I and many other experts strongly believe that a runner who takes full advantage of *every* legitimate means to enhance performance can reach the same performance level that he or she would reach through the shortcut of doping (not to mention sustain it longer and do it without ruining his or her long-term health). In addition to cutting-edge nutritional practices, effective alternatives to cheating may include sleeping in an altitude simulation tent, cross-training, better mental preparation, running technique improvement, and state-of-the-art injury avoidance and treatment measures.

It's difficult to overstate the performance-enhancing potential of natural foods and dietary supplements. In fact, proper nutrition is itself an important facet of training effectively, preventing injuries, and almost everything else you do as a runner. Imagine you have an identical twin, also a runner, with whom you train every day. The only difference between the two of you is that your diet and sports nutrition habits are careless, whereas your twin's diet and sports nutrition habits are based on sound principles and the latest knowledge. Who will have better results? Science tells us your twin will perform better in workouts, recover faster from workouts, gain fitness faster, develop a leaner body composition, be able to handle a heavier training load, get sick less often, suffer fewer injuries, and, most of all, kick your

butt in races! And if you don't wise up and start eating and drinking as your twin does, he or she will continue running strong long after age slows you down and will even outlive you. That's how important it is to learn how to fuel your body properly.

I use the term "performance nutrition" with deliberate awareness of the way it echoes "performance-enhancing drugs," because I want runners to understand that it is just as powerful. Performance nutrition is simply a systematic approach to using food and nutritional supplements to enhance running performance. There are six specific objectives of using nutrition in this way, what I call the Six Pillars of Performance Nutrition:

1. Enhance your general health
2. Maximize your body's adaptations to training
3. Fuel running performance
4. Enhance post-exercise recovery
5. Prevent injuries and sickness
6. "Improve on nature"

In this chapter, I will speak generally about these six components of performance nutrition for runners. In the context of these explanations, I will also introduce to you some of the key nutrients, terms, and concepts that will come up again in later chapters, which are entirely devoted to delivering practical strategies to achieve optimal performance nutrition.

USING NUTRITION TO ENHANCE YOUR GENERAL HEALTH

Running fitness and general health are not identical, but they overlap substantially. For example, running fitness depends in part on having a strong heart and excellent blood circulation. These same attributes

are also associated with longevity, as they reduce the risk of common causes of death such as stroke and heart attack. Running fitness also depends on having a lean body composition (low body fat percentage), which in addition to helping you run well reduces your risk of diabetes, Alzheimer's, and other diseases.

Because there is so much overlap between running fitness and general health, virtually every factor that has a positive effect on your health is likely to have a positive effect on your running fitness. Examples of such factors are getting adequate sleep and practicing effective stress management. Another one is, of course, nutrition. Maintaining a healthy diet will enhance your overall health in a variety of ways, and a majority of these positive health effects will carry over into your running.

Let's consider aging. One well-known cause of aging is damage to body tissues caused by free radicals, mainly oxygen radicals, which are produced as a normal by-product of aerobic metabolism. Oxygen radicals are missing one electron, making them highly unstable and causing them to steal electrons from healthy tissues. This process can instigate a chain reaction of damage to cell membranes, DNA, and other body proteins. The body uses antioxidant defenses—including enzymes such as superoxide dismutase and nutrients like vitamin E—to prevent and limit free radical damage, but in the long run it's a losing battle. The accumulation of such damage leads to declining function in every organ and system of the body. It is also implicated in the development of a variety of degenerative diseases, including cancers and coronary heart disease.

Good nutrition can bolster antioxidant defenses and thereby slow the aging process. Recent research on simple organisms has shown that increasing the concentration of key antioxidants through genetic manipulation and other means can drastically increase life span. Numerous studies with humans have demonstrated that diets rich in anti-

oxidants such as vitamins C and E and carotenoids reduce the risk and in some cases slow the progression of cancers, Alzheimer's disease, and other degenerative diseases.

The accumulation of free radical damage to body tissues that comes with aging is also one of the primary reasons our running performance declines as we age. As consequences of this damage, our muscles become weaker and less elastic, our heart muscle loses power, and so forth. Good nutrition helps us better maintain our running performance over the years—not to mention enhances it at any age, including in the very prime of life—by strengthening the body's antioxidant defenses. Exercise itself strengthens the body's antioxidant defenses, slowing the aging process and boosting our ability to resist muscle damage during exercise and recover quickly between runs. But the size of this boost depends on how well it is supported by the right nutrition. Consistent training and good nutrition therefore work synergistically to keep us young and swift.

So how exactly do you eat to maximize your general health? In the following chapter, I will identify four simple rules of healthy eating and show you how to follow them.

USING NUTRITION TO MAXIMIZE TRAINING

Running fitness is not a single thing but is rather a collection of interrelated physiological changes in the body that occur in response to training. Individual workouts challenge the functional limitations of our organs and systems (the cardiovascular system, the endocrine system, and so forth). Such stress signals the genes that regulate the affected organs and systems to respond by producing more of certain proteins and less of others—whatever it takes to make the organ or system in question better able to handle the stress of the next workout. The sum of these changes is steadily improving running fitness:

the ability to run faster, farther, more efficiently, and with less chance of injury.

The itemized list of adaptations that occur in the body in response to training is long—and getting longer as exercise scientists continue to explore deeper into the frontier of the human body at work. While exercise stimulates these adaptations, it is the nutrients in your diet that produce them. In other words, exercise only creates a demand in your body for the nutrients that are needed to make fitness-boosting changes. It is nutrition that fulfills this demand. Following are examples of important fitness adaptations that occur in several areas of the body in response to a consistent, progressive running program complemented by an appropriate dietary regimen.

REDUCED BODY FAT

To be healthy, the average human male must have a minimum of 5 percent body fat and the average female must have a minimum of 10 percent body fat. Carrying too little body fat can cause a variety of serious health problems, including immune system depression and reproductive disorders. On the other hand, carrying much more than the minimum amount of body fat required for health has disadvantages in terms of running performance because it adds to the load that the muscles must transport. In one study, the addition of 1 kilogram (2.2 pounds) of weight was shown to increase the energy cost of running by 3.5 percent. This loss of economy would turn a 40-minute 10K runner into a 41:28 10K runner. While body fat is not exactly "dead weight"—as it provides a source of energy during low- to moderate-intensity running—even the leanest healthy runners have enough body fat to provide far more energy than they could ever use in a single run.

Training improves body composition by reducing body fat content while preserving muscle. Body fat tends to decrease when more calories are burned than consumed day after day. When a caloric deficit

is achieved without exercise, both muscle and body fat are lost. When it is achieved with exercise, more fat and little to no muscle are lost, because exercise creates a demand for muscle tissue, so that more of the calories consumed are used to rebuild and maintain muscle tissue than to replace burned body fat.

ENHANCED BLOODFLOW

The most important job of the blood during running is to transport oxygen to your muscles (including your heart). The more oxygen your blood is able to deliver, the longer you will be able to sustain faster running speeds. Training results in some important blood changes that enhance its ability to deliver oxygen.

Training increases blood volume by as much as 10 percent. It also increases the number of oxygen-carrying proteins attached to red blood cells. Even the dilating capacity of the blood vessels increases as you become fitter. Wider blood vessels allow greater bloodflow.

Nutrients participate in all of these adaptations. A good example is iron, a trace mineral (i.e., a mineral needed in very small amounts) that is necessary for the formation of hemoglobin, a protein that binds oxygen molecules to red blood cells, and myoglobin, a similar protein that transports oxygen into the muscle cells. Training increases the concentration of iron-storing proteins in the body. Consequently, it also increases the number of hemoglobin molecules per red blood cell, as well as the concentration of myoglobin.

STRONGER BONES

Perhaps the most important early adaptation to running is improvement in the capacity of the bones of the lower extremities to absorb ground impact forces without breaking down. When subjected to a regular schedule of repetitive impact forces, the bones of the lower extremities remodel their structure to become stronger and denser.

This remodeling process is essentially a healing response to impact trauma, which works out for the best as long as running volume is increased very gradually and adequate recovery time is always allowed. If the bones are subjected to too much stress too soon, damage will outpace remodeling and a bone strain will result. Bone strains in the tibia (the smaller of the two shin bones) are the most common injury in beginning runners. A severe bone strain can develop into a stress fracture.

Various nutrients play important roles in the impact-related adaptations of bones. The primary components of bone tissue are collagen (a protein) and the minerals calcium and phosphate.

INCREASED BRAINPOWER

Contrary to what you might assume, the brain contributes more to running performance than any other part of the body. First of all, the "program" for the action of running is stored in your brain (like software in a computer), and the more you run, the more this pattern is refined to become increasingly efficient, so you can run at faster speeds with less energy.

Fatigue is also controlled by the brain. While you run, your brain constantly monitors feedback from your body—the temperature of your muscles, the amount of glucose in your bloodstream, the amount of oxygen reaching your heart—to determine whether your health is in any danger. When your brain decides that you may be running yourself into harm's way, it will cut back on the electrical signals it sends to your muscles, forcing you to slow down. It is this "voluntary" slowdown rather than events in your muscles themselves that constitutes fatigue.

The brain is certainly the most adaptable organ in the body. In fact, it is the only organ that adapts to running *while* you're running. Everything else adapts during the recovery periods between workouts. Nutrition affects the performance of the brain during exercise in a

variety of ways. For example, consuming carbohydrate during exercise signals your brain that it is safe to send stronger electrical signals to your muscles, allowing you to run harder, because there's an extra fuel supply to supplement what's already stored in your body.

STRONGER HEART

The heart muscle becomes much larger and more powerful in response to training. This allows it to pump a lot more blood per contraction, substantially increasing the maximum rate of oxygen supply to the muscles. Research has shown that the heart stroke volume (i.e., the amount of blood pumped per contraction) of elite runners is often twice that of sedentary individuals. As with all muscles, proteins are the primary structural ingredients of the heart, so its growth involves the accretion of many new proteins in this vital organ.

MORE EFFICIENT MUSCLES

Skeletal muscles adapt to training in literally dozens of known ways, and probably in dozens more ways that are yet to be discovered or fully understood. I'll highlight a few of these changes.

The muscles adapt to impact forces through an injury-response mechanism similar to that of the bones. Various muscles, especially the calves and quadriceps, help the body absorb impact forces by contracting eccentrically—that is, by resisting their own lengthening. Because eccentric contractions essentially pull muscles in two directions simultaneously, they often damage individual muscle fibers. The damaged tissues respond, over time, by remodeling themselves in such a way as to become more resistant to eccentric rupturing.

Running also stimulates big gains in the muscles' capacity to extract oxygen from the bloodstream and use it to metabolize fats, carbohydrate, and to a lesser extent, amino acids for energy. This process depends on capillaries, which are tiny blood vessels that carry oxygen

into muscle cells; myoglobin, a protein that transports oxygen molecules within muscle cells; mitochondria, which are the intracellular sites where oxygen is used to break down fats and carbohydrates; and mitochondrial enzymes, which allow this process to take place extremely fast. Training increases the density of capillaries in the muscles, their myoglobin concentration, the number of mitochondria within the muscle cells, and the concentration of mitochondrial enzymes. In addition, it increases glucose and fatty acid transporters in the muscle cell membranes, which in turn increases the efficiency with which the muscle cells can draw carbohydrate and fat fuel from the blood.

Another important muscular adaptation is improved carbohydrate storage. In longer runs, depletion of carbohydrate fuel stores can be a major contributor to fatigue and exhaustion. Most often the problem is depletion of glycogen stores in the leg muscles, but sometimes hypoglycemia—that is, low blood glucose—occurs first. Hypoglycemia results when glycogen is depleted from the liver, as the liver is responsible for regulating blood glucose levels by breaking down glycogen into glucose and releasing it into the bloodstream as necessary.

The carbohydrate storage capacity of the human body is small. The average adult stores about 500 grams of glycogen (400 grams in the muscles and another 100 grams in the liver), as compared to 12 to 18 kilograms of fat. Training can greatly increase the body's glycogen storage capacity. The leg muscles of an elite runner may contain three times as much glycogen as the legs of a sedentary adult. This adaptation allows the well-trained runner to run a heck of a lot farther at relatively high speeds.

Clearly, nutrition plays a significant role in this adaptation, because all of the body's stored glycogen comes from dietary sugars and starches. Also, runners can effectively increase their carbohydrate stores by consuming a sports drink or gel while running. I'll discuss this topic in depth in Chapter 5.

USING NUTRITION TO FUEL RUNNING PERFORMANCE

The expression "You are what you eat" effectively conveys the idea that the nutrients in our diet become the tissues and organs of our bodies. What it fails to convey is the fact that a number of nutrients play active roles during exercise. In other words, you also *do* what you eat.

Following are descriptions of 10 such nutrients and their running-specific roles. There is more detail in these descriptions than you need to commit to memory, but I include it nonetheless for two reasons: first, because these important nutrients will come up again in later chapters; and second, in case you are as fascinated by the workings of the human body as I am.

Branched-chain amino acids. Amino acids are best known as the building blocks of proteins, but they also function in their free form in the body. There are 20 amino acids, three of which—leucine, isoleucine, and valine—are referred to as branched-chain amino acids because of their structure. Unlike other amino acids, branched-chain amino acids can be directly oxidized for energy within muscle cells rather than having to be converted first to glucose in the liver. The muscles initially rely only minimally on branched-chain amino acids during running, but this reliance becomes greater in the later stages of long runs, when the muscles' preferred energy source—glycogen (the storage form of glucose)—runs low. Training enhances the body's capacity to release energy from amino acids during running. This adaptation results in greater endurance.

Calcium. When we think of calcium, we usually think of bones. It's true that 99 percent of the calcium in the human body is contained in bones as calcium phosphate. But calcium also plays a critical role in

muscle action. Positively charged calcium ions located at the neuromuscular junction (the point where nerves attach to muscles) are needed to turn an electrical impulse from the brain into a chemical action causing muscle fibers to contract and relax. Diminishing calcium stores at the neuromuscular junction are closely associated with muscle fatigue.

Fats. Most of the fats, or fatty acids, in the body are stored as triglycerides in adipose tissue deposits (fat layers beneath the skin) throughout the body. Even in very lean runners these energy stores are vast compared to carbohydrate stores (mainly glycogen in the muscles and liver), but they are not as easy to access, which is one reason fats are not the muscles' preferred energy source during intense exercise. In order for the body to use them, triglycerides must be converted to free fatty acids and transported to the muscles through the bloodstream, whereas glycogen is available within the muscle cells.

Scientists often measure exercise intensity as a percentage of VO_2max, where 100 percent VO_2max is the maximum rate at which a given athlete's body is able to consume oxygen. At 40 percent VO_2max (an easy jog), fats supply about 50 percent of muscle energy in a typical trained runner. At 80 percent VO_2max (a comfortably brisk run), fats supply only 5 percent of muscle energy. But runners vary widely in their reliance on fat. Some are "natural fat burners" who use more fat and less carbohydrate at any running intensity. Such runners are best suited to racing at longer distances because they are able to conserve their glycogen stores longer.

A small amount of triglycerides are stored within the muscles. These fats are more accessible than adipose triglycerides and are probably the only fats used for muscle energy above 95 percent VO_2max. Training enhances the body's capacity to deliver free fatty acids to the muscles and to oxidize fats within muscle cells.

Glucose/glycogen. Glucose and chains of glucose molecules called glycogen are the primary sources of muscle energy during moderately high- to high-intensity running. They provide virtually all of the energy for sustained running above 95 percent VO_2 max in most runners (except during all-out sprinting, when creatine phosphate is used). Glucose and glycogen are derived from sugars (including glucose itself) and starches consumed in the diet. Training increases the body's capacity to store glycogen in the muscles and liver and to burn glucose and glycogen efficiently. It also enhances the ability of the liver to convert lactate, a product of incomplete glucose metabolism, and amino acids to glucose.

Glutamine. Glutamine is the most abundant amino acid in the blood and skeletal muscles. Most of the body's glutamine is in fact produced by the muscles. It is an important fuel for many cells of the immune system. During running, glutamine also provides an additional source of glucose to fuel muscle contractions. It is sent from the muscles to the liver and converted to glucose, which is then sent back to the muscles to provide energy. Prolonged exercise can result in significant glutamine depletion, not only because the liver uses it to produce fuel for the muscles, but also because exercise increases the demand for glutamine in the immune system cells and in tissues (particularly the gut) that use it directly.

Post-exercise glutamine depletion leaves the body more susceptible to bacterial and viral infections. Runners who maintain a proper diet and avoid overtraining are able to quickly recover normal glutamine levels, but runners who do not may develop a chronic glutamine deficit that will likely compromise performance and health. Low blood glutamine levels are commonly seen in runners suffering from overtraining syndrome, a form of chronic fatigue that affects some elite athletes.

Magnesium. Magnesium belongs to a category of minerals called electrolytes, so called because they conduct electrical signals in the body. It is found in all of the body's cells, although it is most concentrated in the bones, muscles, and soft tissues. It's a necessary element in more than 300 enzyme reactions involving nerve transmission, muscle contraction, and especially adenosine triphosphate (ATP) production. (ATP is the fundamental energy currency of the body. All other "fuels"—glucose, fats, etc.—are broken down to produce ATP, which in turn stimulates muscle contractions.)

All of the important electrolytes except calcium are lost through perspiration. Heavy sweat losses can therefore interfere with the important functions for which magnesium and other electrolytes are responsible. Low blood magnesium levels during exercise have been cited as a cause of muscle fatigue and irregular heartbeat.

Potassium. Also an electrolyte, potassium is necessary for nerve transmission, muscle contraction, and glycogen formation. It also aids in maintaining cardiovascular system function. During workouts, potassium helps calcium do its job of stimulating muscle contractions. While it is calcium that actually stimulates the contraction, it cannot do so without the aid of potassium. Excessive potassium loss through sweating can lead to heat intolerance.

Sodium/chloride. Sodium and chloride cooperate with water to help maintain the volume and balance of all the fluids outside your body's cells, such as the blood. Sodium, the best-known electrolyte, plays a particularly important role because it helps transport nutrients into cells, so they can be used for energy production as well as tissue growth and repair. In addition, sodium functions in muscle contraction and nerve impulse transmission. Excessive loss of sodium through

sweating may lead to hyponatremia, a dangerous condition that I'll describe further in Chapter 5.

Vitamin E. Vitamin E serves a number of important functions in the body, but while you're running its most important job is antioxidant defense. During exercise, your body produces several times more free radicals, due to the high rate of oxygen consumption, than at rest. These free radicals attack and damage muscle cells, causing damage that impairs muscle function and leads to soreness the next day. Vitamin E is able to neutralize free radicals. Consistent training, combined with a diet rich in vitamin E, increases vitamin E storage in the body and the efficiency of its radical neutralizing actions.

Water. Water is arguably the most important nutrient of all. It accounts for two-thirds of the body's mass and is essential for a host of vital functions including proper digestion, elimination of wastes, and joint lubrication. Perhaps its most running-specific role is in perspiration, which is the body's primary cooling mechanism during running. The downside of perspiration is that the more you perspire, the more water you lose and the less efficient this cooling mechanism becomes. The loss of blood volume that comes with dehydration also hampers cardiovascular performance. Drinking water while running can limit dehydration and its effects. Drinking an enhanced water or sports drink containing electrolytes is preferable because it does a more complete job of counteracting nutrient depletion caused by perspiration.

Of these 10 nutrients discussed, 7 are able to enhance running performance when consumed during running: branched-chain and/or other amino acids, carbohydrates (from which glucose is derived), glutamine, magnesium, potassium, sodium chloride, and water. In Chapter 5, I'll give you detailed guidelines for hydration and nutrition during exercise.

USING NUTRITION TO ENHANCE POST-EXERCISE RECOVERY

Individual workouts stress your body by depleting energy supplies, disrupting muscle tissues, changing hormonal patterns, and so forth. This type of stress is often referred to as a *training stimulus*. After the workout is completed, your body initiates physiological processes designed to restore homeostasis, or the way the body was before the workout. It replenishes muscle energy stores, builds new muscle proteins, adjusts hormonal patterns, and engages in a variety of other responses. Collectively, these various processes that lead back to homeostasis are known as recovery.

There is a very close relationship between acute recovery, which is the body's short-term response to training stimuli, and adaptation, which is the body's longer-term response to repetitive training stimuli. You can think of recovery as a series of short trips that add up to the lengthy voyage of adaptation, or fitness gains.

Research has shown that nutrition after exercise has a tremendous influence on recovery. If you consume the right types and amounts of nutrients within an hour of completing a workout, your muscles will rebuild and refuel themselves much faster than if you consume the wrong nutrients or nothing at all. And because short-term recovery leads to long-term fitness adaptations, consistently practicing smart recovery nutrition will make you a better runner over time. Recovery nutrition will be our subject in Chapter 7.

USING NUTRITION TO PREVENT INJURIES AND SICKNESS

In almost every respect, runners are healthier than the population at large. There are only two small exceptions: runners experience more

musculoskeletal injuries (muscle strains, bone strains, and so forth) than non-runners, and runners who train especially hard tend to suffer cold and flu more often than the average person. Nutrition can help in both of these areas.

There is evidence that proper recovery nutrition can reduce injuries by accelerating the repair of tissues damaged during running. A well-balanced overall diet that contains plenty of the various nutrients needed to make the bones, muscles, and connective tissues strong will also reduce injuries. For example, studies have shown that runners who eat too little fat experience more injuries than runners who eat more fat. Deficiencies in any of a number of other nutrients—amino acids used to rebuild damaged muscles, calcium and phosphate for bone density, and so forth—could also make you more susceptible to injury.

The best defense against cold and flu is, naturally, a strong immune system. The immune system depends on proper nutrition to function optimally. To name just a few examples of specific nutrients that support immune function, vitamin C increases antibody production; vitamin A promotes mucus production (mucus prevents foreign invaders in the body from gaining access to the bloodstream); amino acids, fats, and carbohydrate provide energy for cells of the immune system; and fatty acids produce prostaglandins, hormonelike substances some of which act as mediators in the inflammation response to infection.

Inadequate or excessive intake of certain nutrients can hamper immune defenses in various ways. In the typical American diet, the most common immunosuppressive dietary problems are excessive intake of total calories (i.e., being overweight), saturated fat, refined sugars, and caffeine.

During exercise, various aspects of immune system function are enhanced. Consistent daily exercise leads to a general strengthening of these functions. Much has been made of the fact that very intense and

very long workouts temporarily suppress the immune system. However, the immunosuppressive effect of such workouts is much smaller in those who exercise regularly than in those who are sedentary. Nevertheless, while most runners experience fewer infections (cold, flu, etc.) than non-runners, there is some clinical evidence, and plenty of anecdotal evidence, that chronic heavy training slightly increases infection risk. Long-term inadequate recovery from training can lead to overtraining syndrome, a serious hormonal disorder in which depression of the immune system is often a secondary symptom.

A classic example of nutrition-exercise synergy is the fact that consuming carbohydrate during and immediately after a hard run reduces immunosuppression. David Nieman of Appalachian State University led one of several studies proving this effect. His team found that athletes who used a sports drink during exercise showed significantly reduced signs of immunosuppression afterward compared to a control group. That's one more reason to use a sports drink!

USING NUTRITION TO "IMPROVE ON NATURE"

While natural foods are the best source of nutrition for most meals and snacks, nutritional supplements are sometimes superior when it comes to meeting certain special needs that runners have. Most of the nutritional supplements marketed to athletes are useless, but a few have been proven effective in research studies. For example, creatine monohydrate is a nutritional supplement that has been shown to reduce muscle damage during long runs. Although you can get creatine from natural foods such as beef, you can't get it in amounts sufficient to match what you can get with supplementation. So this is one case where a nutritional supplement "improves on nature." I will say a lot more about creatine and a number of other nutritional supplements in Chapter 9.