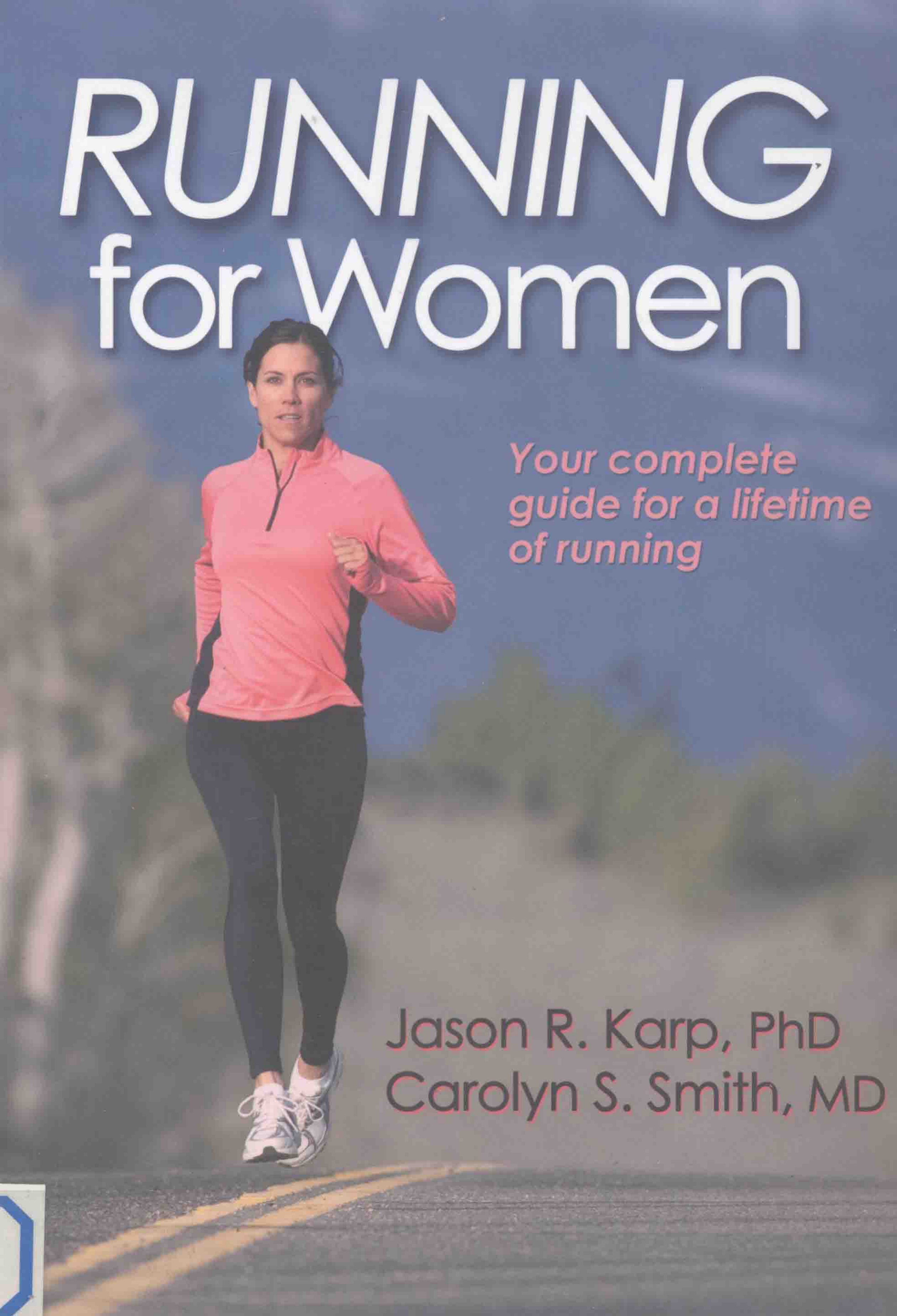
# RUNNING for Women



*Your complete guide for a lifetime of running*

Jason R. Karp, PhD
Carolyn S. Smith, MD

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For my father, Monroe, whose long walking strides caused me to run to keep up. And for my mother, Muriel, a great athlete herself. In her memory, I will personally donate 10 percent of my royalties on every book sold to Susan G. Komen for the Cure.

- Jason Karp

In memory of my grandmother, Gertrude Gallagher Smith, the remarkable matriarch of our family who was ahead of her time and a pillar of strength and inspiration to me and women everywhere. And to my first track and cross country coaches, Ben Newson and Dick Greene, who recognized and nurtured my talent and instilled a love for the sport, for which I am forever grateful.

- Carolyn Smith

# Preface

As best-selling author John Gray so decisively pointed out, men and women seem to be from different planets. In addition to the many psychological and behavioral differences, it is evident from the time we are boys and girls that there are also many anatomical, physiological, hormonal, and metabolic differences between males and females. Many of these differences influence girls' and women's response to running, which raises the question: should women train differently than men?

The past few decades have seen a significant rise in the number of physically active women and the number of women competing in running races. Females now account for more than 5.4 million road race finishers nationwide and represent 53 percent of race fields compared to only 23 percent in 1989. Women now exceed the number of male participants in every race distance except the marathon. The half-marathon currently has the largest female percentage (57 percent) of any U.S. road distance, with the percent flipping to a female majority in 2005. By contrast, in 1985, less than 20 percent of half-marathon finishers were female. Of the nearly 468,000 runners who completed a marathon in the United States in 2009, 40.4 percent of them were female.

As a result of the "women's running boom," women's running performances have improved at a much faster rate than those of men, who have been running competitively for a long time. Over the first 40 years of women's official competition in the marathon (1971-2011), the world record improved by 46 minutes and 17 seconds (25.5 percent). In comparison, over the first 40 years of men's official competition in the marathon (1908-1948), the world record improved by 29 minutes and 39 seconds (16.9 percent). At the other end of the distance-running spectrum, women have decreased their time in the mile (1,600 meters) from 6:13 in 1921 to the current world record of 4:12.56, an improvement of 32.3 percent, while men have decreased their time in the mile from 4:28 in 1852 to the current world record of 3:43.13, an improvement of 16.7 percent. Interestingly, women are slightly closer to their male counterparts in the marathon (9.5 percent) than in the mile (13.2 percent), differences that have remained pretty stable since the 1980s.

In response to the popularity of running among women, a great deal of scientific research has been undertaken to understand what characteristics influence the difference in running performance between the sexes, a difference that averages 10.7 percent in favor of men across all running distances, from the 100 meters to the marathon. The research starts with the heart. During puberty, men's hearts grow larger than those of women, creating a larger, more powerful pump. Men also have more oxygen-carrying hemoglobin in their blood, owing to their greater blood volume. Together, the larger heart and greater blood volume create a cardiovascular system that supplies a greater amount of oxygen to the working muscles, giving men a higher aerobic ceiling (expressed physiologically as the maximum volume of oxygen consumed per minute, or $\dot{V}O_2max$). As a result, men are able to sustain a faster running pace. This cardiovascular advantage for men explains why the best female runners don't run as fast as the best male runners in distance races up to the marathon.

In ultramarathons, however, during which the race is run at a slower pace, a narrowing of race performances between the sexes occurs. Cardiovascular differences become less important, and other characteristics, such as fuel use by the muscles and the ability to dissipate heat, become more important. Ultramarathons may represent a unique opportunity for women to excel; scientific research has revealed that women have a greater capacity than men to metabolize fat and conserve their limited store of carbohydrate (glycogen), which may give them an advantage for very long endurance activities. Although men run significantly faster than women at race distances from the 5K to the marathon, they do not run significantly faster in races longer than a marathon and sometimes don't run faster at all. For example, while the women's 5K and marathon world records are 12.4 and 9.5 percent slower than the men's 5K and marathon world records, the women's 100K world record is only 5.3 percent slower than the men's world record. It seems possible that elite women could beat elite men in ultramarathons. Research is revealing that women ultramarathon runners seem to have a greater resistance to fatigue than do equally trained men whose performances are superior up to the marathon distance.

And then, of course, there's estrogen. Whether you are a miler or an ultramarathoner, estrogen is the single biggest factor that differentiates you from the guy running next to you in a race. It is a powerful hormone, influencing many aspects of your physiology, including metabolism, glycogen storage, lung function, and bone health. The more we learn about estrogen, the more runner friendly it seems. Indeed, estrogen is so important to bone health that its deficiency, which is often caused by irregular or absent menstruation caused by a high level of training, is the most significant risk factor for osteoporosis in active women.

Given the widespread effects of estrogen and the cyclic changing of a woman's hormonal environment, it is evident that women should train differently than men or at least alter their training to account for the hormonal changes. So women should no longer simply follow what men are doing. How the changes in estrogen and its sister hormone progesterone across the menstrual cycle affect endurance performance and what implications they have for training is a big part of what this book is about and distinguishes this book from all others on the subject. We wrote *Running for Women* with you, the female runner, in mind. It is the only book that takes an in-depth approach to training female runners and is the resource that all female runners and coaches need. The purpose of this book is to explain what makes female runners unique and examine how these differences affect training, performance, health, and wellness.

The book is divided into three parts. Part I sets the conceptual framework by addressing the physiology of women, beginning with women's differentiating cardiorespiratory, hormonal, metabolic, muscular, and anatomical characteristics. It then discusses how female physiology—menstrual cycle, pregnancy, menopause, and aging—changes the body and affects training and performance. Part II focuses on the principles and components of training and the types of workouts that target women's different training needs and goals. It discusses the best times of the menstrual cycle to do various types of workouts and proposes guidelines for how women can manipulate their training programs around their cycles to maximize results. It also shows how women can use sex differences to their advantage in training and competition. Finally, part III examines the health and wellness of female runners. It discusses the consequences of disordered eating, osteoporosis, and menstrual irregularities (collectively known as the female athlete triad) and includes chapters on common running injuries and nutrition. It also recommends preventive measures to minimize the risk of injury and disease.

In this book, you'll get the perspective of two highly respected doctors and practitioners. As an exercise physiologist, nationally recognized running coach and award-winning personal trainer, speaker, and writer, Dr. Jason has seen firsthand the success that female runners can have when manipulating their training in response to their unique physiology. As a university sports medicine physician, successful ultramarathoner, and U.S. Olympic Marathon Trials qualifier, Dr. Carolyn works with female athletes every day and can appreciate everything that female runners experience. Together, the authors bring a unique combination of research- and medical-based expertise, coaching experience and, at least for one of them, success as a female runner.

This book gives you the information you need to become a faster, better, and healthier runner. More than simply a book on training, what follows is an exploration of the question, "How does an understanding of female physiology influence your training and racing?" In other words, "What's the deal with estrogen?"

# Acknowledgments

I'd like to thank the editorial staff at Human Kinetics, including Tom Heine, Heather Healy, and Laurel Plotzke Garcia; my wonderful agent, Grace Freedson; my twin brother, Jack, for inspiring me to be as good of a writer as he is and for not making nearly as many jokes as he could have about a man writing a book about women; the many women who shared their stories and provided insight to this male writer; and my mother, Muriel, for always telling me how proud she was of me.

- Jason Karp

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- Carolyn Smith

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# Part I
# Physiology

1

# Performance Factors and Sex Differences

Although running may seem like a simple activity, improving your running performance is highly scientific. To be able to run longer than a couple of minutes depends on your ability to supply the working muscles with oxygen and the ability of the muscles to use the available oxygen to convert fuel into usable energy. Whether you run a mile or an ultramarathon, it's almost all about oxygen. Distance-running performance, in particular, involves the integration of cardiorespiratory, muscular, metabolic, and neurological factors that function cooperatively to efficiently transfer the production of energy into running speed.

This chapter first examines the basic physiology of distance running. Understanding how energy is produced for running is the basis for understanding how to train most effectively. After all, if you want to get faster or run without injury, every workout you do should have a specific, physiological purpose. The chapter then examines what makes female runners unique and shows you how to capitalize on that uniqueness. When training to run, it's important to consider sex because men and women have different physiological, hormonal, metabolic, and anatomical characteristics.

## Energy Production

As you may have learned in a high school biology class, the energy to move your body comes from the chemical breakdown of a high-energy metabolic compound found in your muscles called adenosine triphosphate, or ATP. ATP is broken down into its two constituents: adenosine diphosphate (ADP) and inorganic phosphate ($P_i$). Because your muscles store only a small, emergency amount of ATP, you must constantly resynthesize it before you can break it down. The formation and resynthesis of ATP is thus a circular process: ATP is broken down into ADP and $P_i$, and then ADP and $P_i$ combine to resynthesize ATP (figure 1.1). Simplistically speaking, running faster comes down to increasing the rate at which ATP is resynthesized so it can be broken down to liberate energy for muscle contraction.

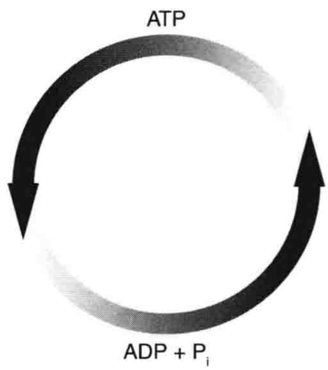


**Figure 1.1** ATP breaks down into ADP and $P_i$, which recombine to create ATP again.

Like many other animals, humans produce ATP through three metabolic pathways that consist of many enzyme-catalyzed chemical reactions. Two of these pathways, the phosphagen system and anaerobic glycolysis, do not use oxygen to create ATP and are therefore referred to as anaerobic. The third pathway uses oxygen to create ATP and is therefore referred to as aerobic.

## Phosphagen System

During short-term, intense activities, your muscles need to produce a large amount of power, creating a high demand for ATP. The phosphagen system, also called the ATP-CP system, is the quickest way to resynthesize ATP. Creatine phosphate (CP), which is stored in the skeletal muscles, donates a phosphate to ADP to produce ATP:

$$ADP + CP \rightarrow ATP + C$$

This process does not use carbohydrate or fat; the regeneration of ATP comes solely from stored CP. Because this process does not need oxygen to resynthesize ATP, it is anaerobic, or oxygen independent. As the fastest way to resynthesize ATP, the phosphagen system is the predominant energy system used for all-out sprinting that lasts 10 to 15 seconds. For all-out running that lasts between 15 and 30 seconds, both the phosphagen system and anaerobic glycolysis provide energy. However, because a limited amount of CP and ATP is stored in your muscles, fatigue occurs rapidly.

## Anaerobic Glycolysis

Anaerobic glycolysis is the predominant energy system used for all-out running that lasts from 30 seconds to about two minutes (about 200 to 800 meters) and is the second-fastest way to resynthesize ATP. During anaerobic glycolysis, carbohydrate, either in the form of glucose (sugar) in your blood or its stored form of glycogen in your muscles and liver, is broken down through a series of chemical reactions. Every molecule of glucose broken down through glycolysis produces two molecules of usable ATP. Thus, this pathway produces very little energy, but the trade-off is that you get the energy quickly, so you can run fast.

You rely on anaerobic glycolysis when oxygen is not supplied fast enough to meet your muscles' needs for ATP. When this happens, your muscles lose their

## Myths of Lactic Acid

As a runner, you have probably heard a lot about lactic acid, especially concerning its relationship to fatigue. Lactic acid gets a bad rap. Lactic acid is the final chemical product of glycolysis and is produced when oxygen is not supplied fast enough to meet your muscles' needs for energy. From the time Nobel Prize winners A.V. Hill and Otto Meyerhof discovered in the 1920s that lactic acid is produced during fatiguing muscle contractions in the absence of oxygen, lactic acid has been the scapegoat for fatigue. Before debunking the myth, let's deal with the semantics. Lactic acid does not exist or function as such inside your body. When lactic acid is produced in your muscles, it immediately converts to lactate, which is a different chemical compound.

No experimental evidence exists proving a cause-and-effect relationship between lactate and fatigue. Fatigue is caused by several things, depending on the intensity of the activity, none of which have to do with lactate. While lactate increases dramatically when you run fast, so do other metabolites, including potassium and the two constituents of ATP: ADP and $P_i$. Scientists have found that these other metabolites cause fatigue by affecting different aspects of muscle contraction. Part of the confusion likely results from the fact that scientists use blood lactate as an indirect measure of acidosis because measuring the lactate concentration in your blood is easy.

While lactate rises in your muscles when they rely heavily on anaerobic glycolysis for energy, which occurs during races from 400 meters to 10K, we often hear runners, coaches, and television commentators also talk about lactic acid in races like the marathon, especially when it comes to recovery strategies afterward to *flush out the lactic acid*. However, in half-marathons, marathons, and ultramarathons, lactate does not accumulate because you run those races at a speed below your acidosis threshold, the fastest sustainable aerobic speed above which acidosis occurs; see the section on metabolic factors (page 12) later in this chapter. At these distances, your muscles become depleted of glycogen. If no carbohydrate is left in your muscles, there is no glycolysis, and lactate cannot be produced. At the finish line of a marathon, your blood lactate level is no different than it was at the start line.

In races in which lactate does accumulate (400 meters to 10K), microscopic proteins transport the lactate to other places, such as the heart and liver, where it is used for fuel. Your heart uses lactate as a fuel and your liver, when it senses that your glycogen stores and blood glucose are running low, converts lactate into glucose so you can continue relying on glycolysis and maintain a fast running pace. Your liver is very smart.

Lactate has also been wrongly pegged as causing a sensation of burning in the muscles during intense exercise and muscle soreness in the days after a hard workout. Lactate does not cause muscle acidosis and so does not cause burning. As for the soreness, muscle and blood lactate return to their preexercise, resting levels in 30 to 60 minutes after your workout, so any lactate that accumulated during the workout is long gone by the time you feel sore. Muscle soreness is the result of training-induced microscopic tears in the muscle fibers, followed by inflammation. This is a normal part of training. The soreness typically worsens during the first 24 hours after exercise, peaks from 24 to 72 hours, then subsides in five to seven days as the muscles heal.

ability to contract effectively because of an increase in hydrogen ions, which causes the muscle pH to decrease, a condition called acidosis. The concentration of other metabolites, including potassium ions and the two constituents of ATP (ADP and $P_i$) also increases. Acidosis and the accumulation of these other metabolites cause several problems inside muscles. These include inhibition of specific enzymes involved in metabolism and muscle contraction; inhibition of the release of calcium, which is the trigger for muscle contraction, from its storage site in muscles; and interference with muscles' electrical charges, ultimately leading to a decrease in muscle force production and your running speed.

## Aerobic System

Because humans evolved for aerobic activities, it's not surprising that the aerobic system, which is dependent on oxygen, is the most complex of the three energy systems. The metabolic reactions that take place in the presence of oxygen are responsible for most of the energy your cells produce. Races longer than two minutes (800 meters to ultramarathons) rely most heavily on the aerobic system. However, aerobic metabolism is the slowest way to resynthesize ATP. The aerobic system uses blood glucose, muscle and liver glycogen, and fat as fuels to resynthesize ATP. The aerobic use of carbohydrate produces 38 molecules of ATP for every molecule of glucose broken down. Thus, the aerobic system produces 19 times more ATP than does glycolysis from each glucose molecule. If that sounds like a lot, using fat gives you much more ATP—a whopping 130 molecules of ATP, give or take, depending on the specific fatty acid being used.

As a distance runner, your running performance, whether recreational or elite, depends mostly on the aerobic system. The more developed your aerobic system, the faster you'll be able to run before you begin to rely on the anaerobic energy pathways and experience the consequent fatigue. The next section takes a look at the factors involved in synthesizing ATP aerobically because these are the factors you'll want to improve with training.

Which pathway you use for the primary production of ATP depends on how quickly you need it and how much of it you need. Sprinting, for instance, requires energy much more quickly than jogging, necessitating the reliance on the phosphagen system and anaerobic glycolysis. Conversely, running a 10K or marathon relies more heavily on the aerobic system. Regardless of how quickly or slowly you run or the type of workout you're running, you never produce ATP through only one energy system, but rather by the coordinated response of all three energy systems contributing to different degrees.

Think of three dials that are always being adjusted to optimize the production of energy. When you race 100 meters, the phosphagen dial is turned up very high, while the other two dials are turned down low. When you run a marathon, the aerobic-system dial is turned up very high, while the other two dials are turned down low. When you race a 5K, the aerobic-system dial is turned up high, the anaerobic-glycolysis dial is turned to medium, and the phosphagen system dial is turned down low.

## Cardiovascular Factors

Cardiovascular factors influencing running include those that affect the volume of blood your heart pumps and the transportation of oxygen to your muscles. When you run, your heart sends blood to places that demand it, such as your skeletal muscles. The amount of blood your heart pumps with each beat is called the stroke volume and is dependent on several factors: the heart's ability to contract quickly and forcefully so it can squeeze blood out of its left ventricle, the quick return of deoxygenated blood from the muscles back to the heart through the venous circulation so that oxygenated blood can be pumped out again from the heart, the amount of pressure in the left ventricle and in the aorta, and the size of the left ventricle.

Having a lot of pressure in the left ventricle as it is filling with blood is beneficial because it creates a stretch on the walls of the left ventricle, which will then contract more forcefully and push out a lot of blood. On the other hand, excessive pressure in the aorta creates a large pressure head that the heart must work against as it pumps blood. The larger the left ventricle, the more blood it can hold; the more blood it can hold, the more it can pump. One of the most elegant adaptations to distance-running training is an increase in the size of the left ventricle of the heart so it can generate a larger stroke volume. Since it was first documented in seven-time Boston Marathon winner Clarence DeMar, scientists and physicians have recognized that an enlarged heart as a result of endurance training, known as *athlete's heart*, is a positive physiological adaptation.

If you multiply your stroke volume by your heart rate (the number of times your heart beats per minute), you get cardiac output, the volume of blood your heart pumps per minute. How high your cardiac output is when you are running at your heart's maximum capability to pump blood (1.5- to 2-mile race pace [2,400-3,200 meters]) is extremely important for your success as a distance runner and is one of the key factors you want to improve.

Once the blood leaves the heart, its flow to the muscles depends on a number of factors. These include the redistribution of blood away from other, less important, tissues to the active muscles, and the resistance of blood flow through the blood vessels. It also depends on the adequate dilation of blood vessels, which depends on the interplay between two branches of your nervous system and their associated hormones: the sympathetic (excitatory, causing vasoconstriction) and parasympathetic (calming, causing vasodilation) nervous systems. Flow to the muscles also depends on the oxygen-transport capacity of the blood, which is determined by red blood cell volume and the amount of hemoglobin, which transports oxygen in the red blood cells; the amount of myoglobin, which transports oxygen in the muscles; and the density and volume of capillaries within the muscle fibers. The greater the network of capillaries around your muscle fibers, the shorter the diffusion distance is for oxygen from the capillaries to the mitochondria, the important microscopic factories responsible for aerobic metabolism.