urethra. These parts produce and maintain sperm cells (spermatozoa). Components of the male reproductive system also transfer sperm cells into the female reproductive tract.

The female reproductive system consists of the ovaries, uterine tubes, uterus, vagina, clitoris, and vulva. These organs produce and maintain the female sex cells (egg cells, or oocytes), transport the female sex cells within the female reproductive system, and can receive the male sex cells (sperm cells) for the possibility of fertilizing an egg. The female reproductive system also supports development of embryos, carries fetuses to term, and functions in the birth process.

PRACTICE

17. Name and list the organs of the major organ systems.
18. Describe the general functions of each organ system.

1.7 | Anatomical Terminology

To communicate effectively with one another, researchers and clinicians have developed a set of precise terms to describe anatomy. These terms concern the relative positions of body parts, relate to imaginary planes along which cuts may be made, and describe body regions.

Use of such terms assumes that the body is in the **anatomical position.** This means that the body is standing erect, face forward, with the upper limbs at the sides and the palms forward. Note that the terms "right" and "left" refer to the right and left of the body in anatomical position.

Relative Positions

Terms of relative position describe the location of one body part with respect to another. They include the following (many of these terms are illustrated in fig. 1.14):

1. **Superior** means that a body part is above another part. (The thoracic cavity is superior to the abdominopelvic cavity.)
2. **Inferior** means that a body part is below another body part. (The neck is inferior to the head.)
3. **Anterior** (*ventral*) means toward the front. (The eyes are anterior to the brain.)
4. **Posterior** (*dorsal*) means toward the back. (The pharynx is posterior to the oral cavity.)
5. **Medial** refers to an imaginary midline dividing the body into equal right and left halves. A body part is medial if it is closer to midline than another part. (The nose is medial to the eyes.)
6. **Lateral** means toward the side, away from midline. (The ears are lateral to the eyes.)
7. **Bilateral** refers to paired structures, one of which is on each side. (The lungs are bilateral.)
8. **Ipsilateral** refers to structures on the same side. (The right lung and the right kidney are ipsilateral.)
9. **Contralateral** refers to structures on the opposite side. (A patient with a fractured bone in the right leg would have to bear weight on the contralateral—in this case, left—lower limb.)
10. **Proximal** describes a body part that is closer to a point of attachment to the trunk than another body part. (The elbow is proximal to the wrist.) *Proximal* may also refer to another reference point, such as the proximal tubules, which are closer to the filtering structures in the kidney.
11. **Distal** is the opposite of proximal. It means that a particular body part is farther from a point of attachment to the trunk than another body part is. (The fingers are distal to the wrist.) Distal may also refer to another reference point, such as decreased blood flow distal to blockage of a coronary artery.

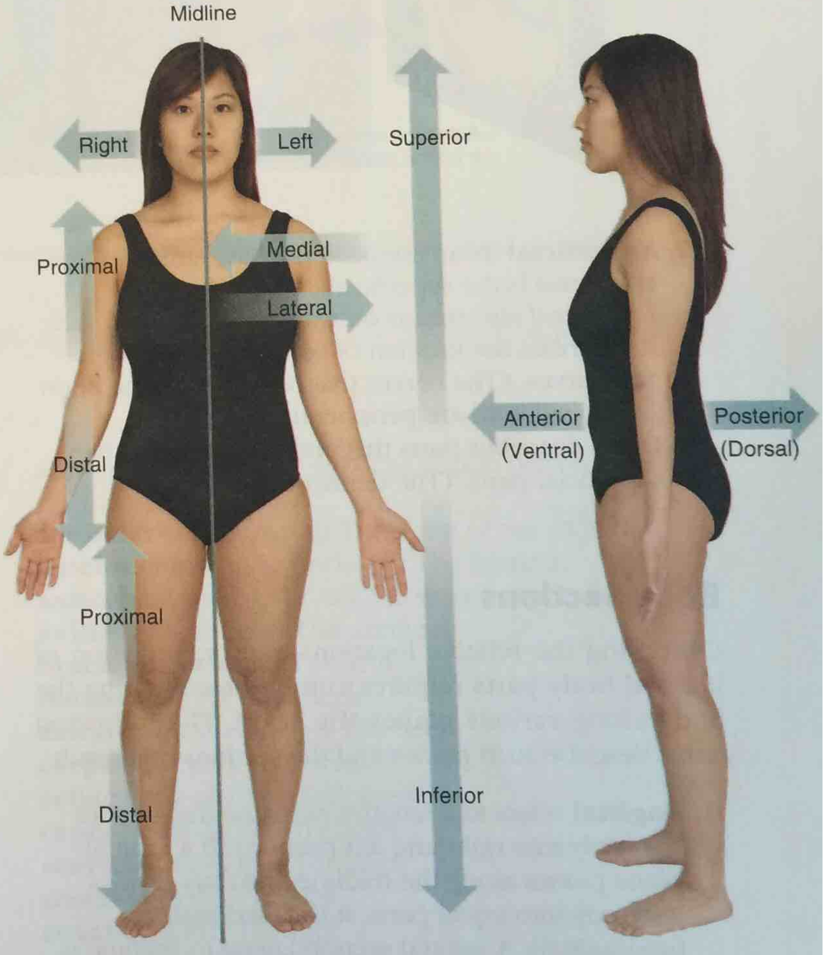

FIGURE 1.14 APR Relative positional terms describe a body part's location with respect to other body parts.

Q *Which is more lateral, the hand or the hip?*
Answer can be found in Appendix F on page 582.

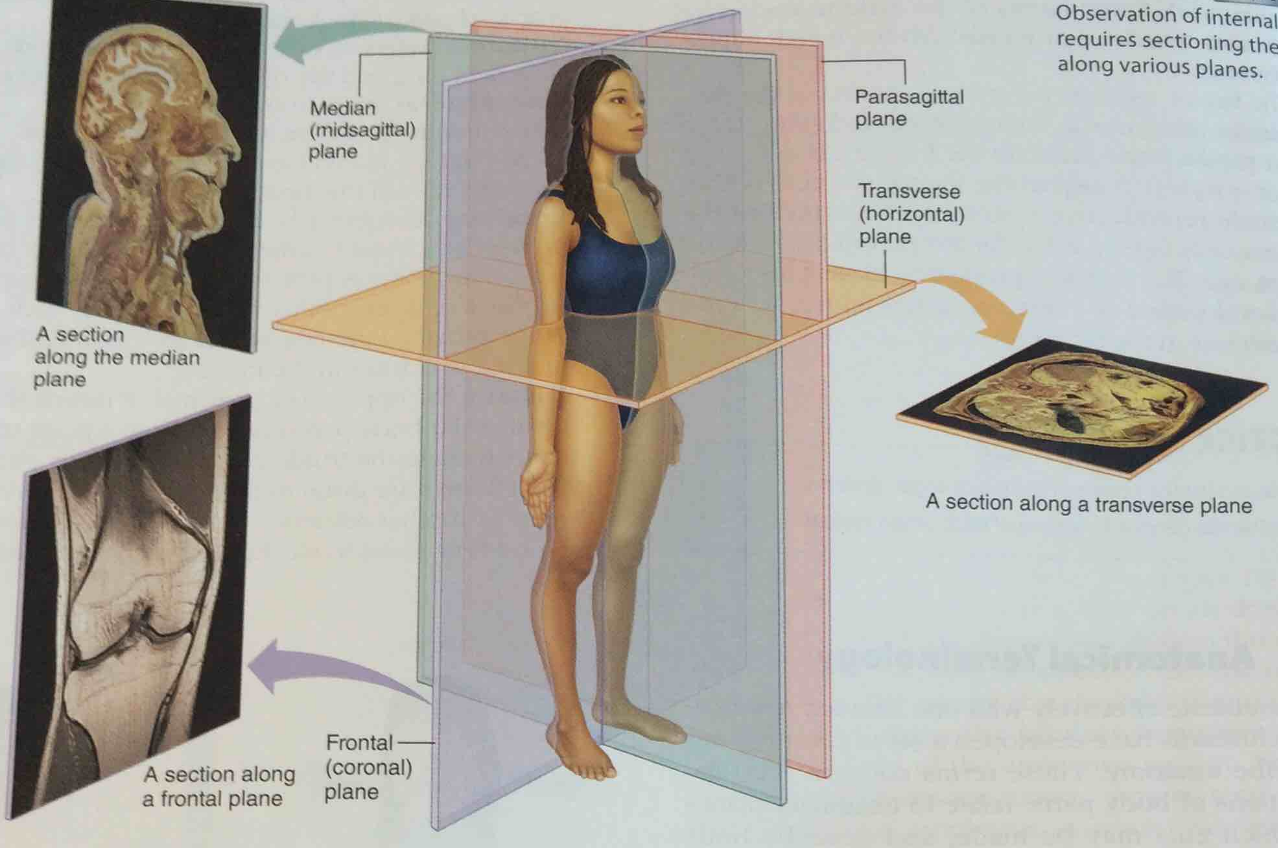

FIGURE 1.15 AP|R Observation of internal parts requires sectioning the body along various planes.

12. **Superficial** means situated near the surface. (The epidermis is the superficial layer of the skin.) *Peripheral* also means outward or near the surface. It describes the location of certain blood vessels and nerves. (The nerves that branch from the brain and spinal cord are peripheral nerves.)
13. **Deep** describes parts that are more internal than superficial parts. (The dermis is the deep layer of the skin.)

Body Sections

Observing the relative locations and organization of internal body parts requires cutting or sectioning the body along various planes (fig. 1.15). The following terms describe such planes and the sections that result:

1. **Sagittal** refers to a lengthwise plane that divides the body into right and left portions. If a sagittal plane passes along the midline and thus divides the body into equal parts, it is called *median* (midsagittal). A sagittal section lateral to midline is called *parasagittal.*
2. **Transverse** (*horizontal*) refers to a plane that divides the body into superior and inferior portions.
3. **Frontal** (*coronal*) refers to a plane that divides the body into anterior and posterior portions.

Sometimes, a cylindrical organ such as a long bone i sectioned. In this case, a cut across the structure is calle a *cross section,* an angular cut is an *oblique sectio* and a lengthwise cut is a *longitudinal section* (fig. 1.1 Clinical Application 1.1 discusses using computeriz tomography to view body sections.

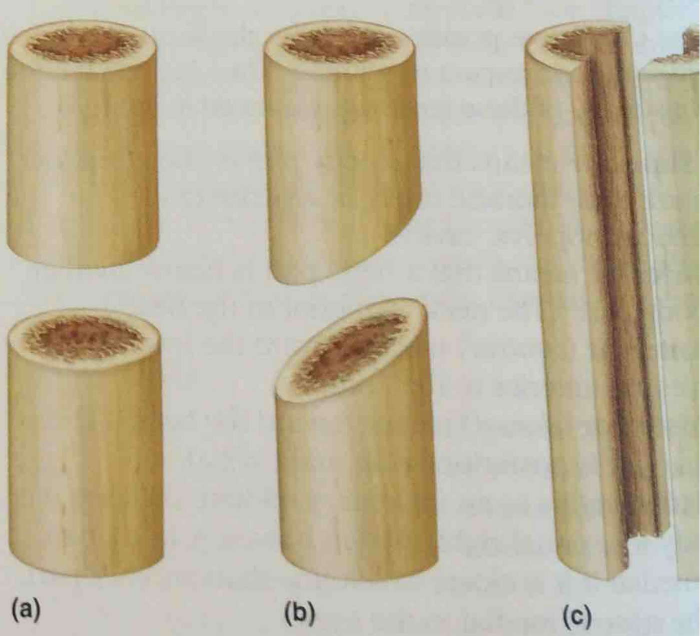

FIGURE 1.16 Cylindrical parts may be cut in **(a)** cross sec **(b)** oblique section, or **(c)** longitudinal section.

1.5 | Maintenance of Life

The structures and functions of almost all body parts help maintain life. Even an organism's reproductive structures, whose primary function is to ensure that its species will continue into the future, may contribute to survival. For example, sex hormones help to strengthen bones.

Requirements of Organisms

Being alive requires certain environmental factors, including the following:

1. **Water** is the most abundant chemical in the body. It is required for many metabolic processes and provides the environment in which most of them take place. Water also transports substances within the organism and is important in regulating body temperature. Water found inside the cells, along with substances dissolved in it, constitutes the intracellular fluid. Similarly, outside of the cells, including the tissue fluid and the liquid portion of the blood (plasma), is the extracellular fluid (fig. 1.4)
2. **Foods** are substances that provide the body with necessary chemicals (nutrients) in addition to water. Some of these chemicals are used as energy sources, others supply raw materials for building new living matter, and still others help regulate vital chemical reactions.

FIGURE 1.4 Intracellular and extracellular fluids.

3. **Oxygen** is a gas that makes up about one-fifth of ordinary air. It is used to release energy from food substances. This energy, in turn, drives metabolic processes.
4. **Heat** is a form of energy. It is a product of metabolic reactions, and the degree of heat present partly determines the rate at which these reactions occur. Generally, the more heat, the more rapidly chemical reactions take place. (*Temperature* is a measure of the degree of heat.)
5. **Pressure** is an application of force to something. For example, the force on the outside of the body due to the weight of air above it is called *atmospheric pressure.* In humans, this pressure is important in breathing. Similarly, organisms living under water are subjected to *hydrostatic pressure*—a pressure a liquid exerts—due to the weight of water above them. In humans, heart action produces blood pressure (another form of hydrostatic pressure), which forces blood through blood vessels.

Health-care workers repeatedly monitor patients' *vital signs*—observable body functions that reflect essential metabolic activities. Vital signs indicate that a person is alive. Assessment of vital signs includes measuring body temperature and blood pressure and monitoring rates and types of pulse and breathing movements. Absence of vital signs signifies death. A person who has died displays no spontaneous muscular movements, including those of the breathing muscles and beating heart. A dead person does not respond to stimuli and has no reflexes, such as the knee-jerk reflex and the pupillary reflexes of the eye. Brain waves cease with death, as demonstrated by a flat electroencephalogram (EEG), which signifies a lack of metabolic activity in the brain.

Organisms require water, food, oxygen, heat, and pressure, but these alone are not enough to ensure survival. Both the quantities and the qualities of such the quantity of food available—that is, food must supply the correct nutrients in adequate amounts.

Homeostasis

Factors in the external environment may change. If an organism is to survive, however, conditions within the fluid surrounding its body cells, which compose its **internal environment,** must remain relatively stable. In other words, body parts function only when the concentrations of water, nutrients, and oxygen and the conditions of heat and pressure remain within certain narrow limits. This condition of a stable internal environment is called **homeostasis** (ho″me-ō-sta′sis).

The body maintains homeostasis through a number of self-regulating control systems, or **homeostatic mechanisms,** that share the following three components (fig. 1.5):

- **Receptors** provide information about specific conditions (stimuli) in the internal environment.
- A **set point** tells what a particular value should be, such as body temperature at 37°C (Celsius) or 98.6°F (Fahrenheit). More about metric equivalents can be found in Appendix C (p. 579); metric units are used throughout this text.
- **Effectors** bring about responses that alter conditions in the internal environment.

A homeostatic mechanism works as follows. If the receptors measure deviations from the set point, effectors are activated that can return conditions toward normal. As conditions return toward normal, the deviation from the set point progressively lessens and the effectors are gradually shut down. Such a response is called a **negative feedback** (neg′ah-tiv fēd′bak) mechanism, both because the deviation from the set point is cor-

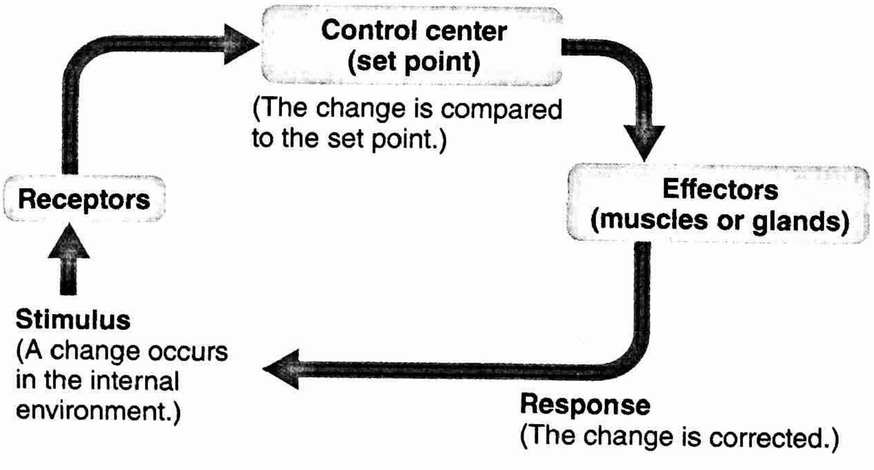

FIGURE 1.5 A homeostatic mechanism monitors a particular aspect of the internal environment and corrects any changes back to the value indicated by the set point.

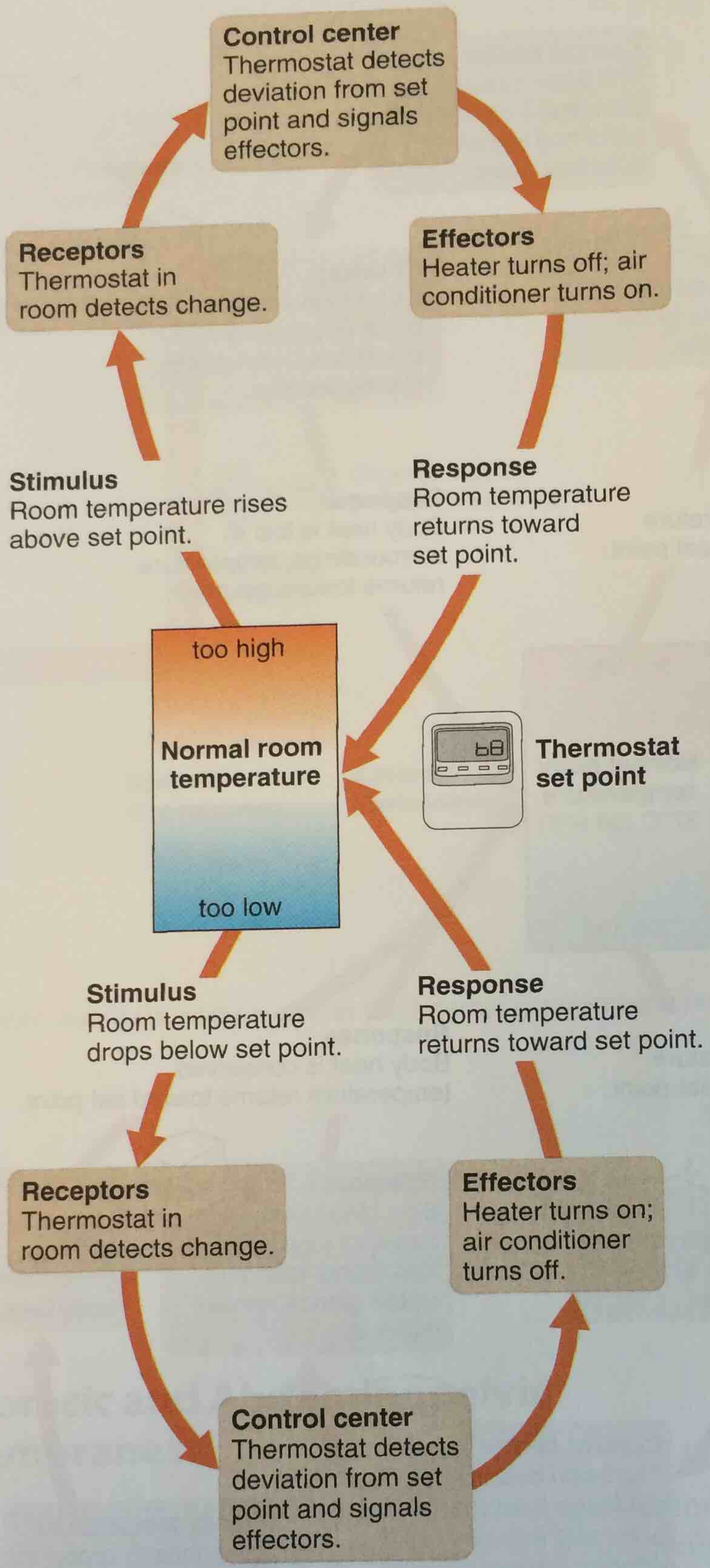

FIGURE 1.6 A thermostat signals an air conditioner and a furnace to turn on or off to maintain a relatively stable room temperature. This system is an example of a homeostatic mechanism.

Q *What would happen to room temperature if the set point were turned up?*

Answer can be found in Appendix F on page 582.

Base, or Introductory, Training

The concept of base, or introductory, training is relatively simple, but the application is slightly more nuanced. Most coaches would agree that the pace of running during this phase is always easy and aerobic (based on the consumption of oxygen), not strenuous and anaerobic (using the oxygen present), and that the volume of training should gradually increase with down, or lesser-volume, weeks used to buffer the increase in volume, aid in recovery, and promote an adaption to a new training load. One systematic approach using a three-week training cycle incorporates four to six days of running training with a weekly increase in volume of 10 percent from week 1 to week 2; week 3 returns to the volume of the first week. For injury prevention, the weekly long run should not be more than 33 percent of the week's total volume. Two or three strength-training sessions emphasizing proper form and movement, not volume of weight, would complement this running training.

For a runner who is training for a race longer than a 10K, this phase of the training cycle is the lengthiest of a training progression because of the slower (relative to speed and muscle development) adaptations to training made by the cardiothoracic systems. Because relatively slow-paced aerobic runs take longer, they require the repeated inhalation of oxygen, the repetitive pumping of the heart, and the uninterrupted (ideally) flow of blood from the lungs to the heart and from the heart to the muscles. All of these actions aid in capillary development and improved blood flow. Increased capillary development aids both in delivering more blood to muscles and in the removal of waste products from muscles and other tissue that could impede the proper functioning of the muscles. However, these adaptations take time. The development of a distance runner may take a decade or more, while the development of faster-paced running can occur in half the time.

A training program that ignores or diminishes the importance of the base training component is a training program that ignores the tenets of exercise science. Without an extensive reliance on easy aerobic running, any performance-enhancement training program is destined for failure. A common question is how long the base period should last. This seemingly simple question does not have a simple answer, but the best reply is that the base period needs to last as long as the athlete needs to develop good running fitness and musculoskeletal strength based on his or her subjective interpretation of how easy the daily runs feel, but not so long that the athlete becomes bored or unmotivated. A good guideline for experienced runners who are training for races longer than 10K is six to eight weeks. Experienced runners training for 10K races or shorter distances need four to six weeks. For beginning runners, the base period takes longer, even making up the bulk of their first four to six months of running. Another common question is how fast the athlete should run. Short of getting a lactate threshold or stress test, which normally indicates approximately 70 to 75 percent of maximum heart rate or 70 percent of $\dot{V}O_2$max, pace charts help determine aerobic training paces based on race performances (Daniels' *Running Formula, Second Edition,* Human Kinetics). They are extremely accurate and offer explanations of how to use the data effectively.

An emphasis on base, or introductory, training does not mean that other types of training are ignored or diminished in importance. The other types of running training—tempo, lactate, threshold, steady-state, hill, and $\dot{V}O_2$max—are relegated to their specific roles in a well-designed training program. Also, neuromuscular development is needed to allow fast performances to occur. These other types of training are meant to sharpen and focus the endurance developed during the base, or introductory, phase. However, because these other types of training also strengthen the cardiovascular and cardiorespiratory systems, they play an essential role in improving performance.

The best approach to strength training during this phase is to perform multiple sets of 10 to 12 repetitions of exercises for total-body strength development. Specifically, at this stage of training, functional strength is less important than developing muscular endurance for the whole body. If this is an athlete's first strength-training progression, the proper execution of the exercise becomes paramount. If an athlete is revisiting strength training after a rest period, becoming reacquainted with the physical demands of combining a running and strength-training program should be the goal. Strength training should be performed two or three times per week; however, one day a week should be entirely free of exercise, so the other workouts need to be performed either on running days after the runs or on the other off days from running if following a four- or five-day-a-week running plan.

Threshold Training

The concept of lactate threshold (LT) often associated with tempo-based running is a conversation point for many exercise physiologists, running coaches, and runners. The science of the concept, the lexicon to describe it, and the appropriate duration and pace of the effort offer endless possibilities for debate and argument. All too often an athlete's successful performance leads to the supposition that his or her interpretation of threshold training (if it is a cornerstone of the program) is the appropriate interpretation and therefore must be copied by the masses. We do not endeavor to make any definitive statements about lactate threshold protocols. We apply the term *threshold* (please feel free to substitute *lactate threshold, anaerobic threshold, lactate turn point,* or *lactate curve*) to describe the type of running that, because of the muscle contractions inherent in faster-paced training, produces a rising blood-lactate concentration that inhibits faster running or lengthier running at the same speed (figure 2.5)—or, less scientifically, a comfortably hard effort that one could sustain for approximately 5 to 6 miles (8 to 10 km) before reaching exhaustion. It is very close to 10K race pace.

Lactate—not lactic acid—is a fuel that is used by the muscles during prolonged exercise. Lactate released from the muscle is converted in the liver to glucose, which is then used as an energy source. It had been argued for years that lactic acid (chemically not the same compound as lactate, but normally used as a synonym) was the culprit when discussing performance-limiting chemical by-products caused by intense physical effort. Instead, rather than cause fatigue, lactate can actually help to delay a possible lowering of blood glucose concentration, and ultimately can aid performance.

Threshold training also aids running performance because it provides a greater stimulus to the cardiothoracic systems than basic aerobic or recovery runs, and it does so without a correspondingly high impact on the musculoskeletal system because of its shorter duration. By running at a comfortably hard effort for 15 to 50 minutes (depending on your goal race and timing of the effort in your training program), you can accelerate the rate at which your cardiothoracic systems develop. Tempo runs, which are often referred to interchangeably with lactate threshold runs, cruise intervals, and steady-state runs, which are slightly slower than tempos, are types of threshold workouts, just at slightly different paces and durations. Ultimately, the objective of a lactate-type run, a measurement of 4 mmol of lactate if blood was drawn at points during the run, would be accomplished performing these runs instead of an easy aerobic run, which would produce almost no lactate.

A good resource on tempo-type training is *Jack Daniels' Running Formula* (Human Kinetics, 2005). The author recommends paces and durations of effort based on the athlete's current fitness and race distances to be attempted. Although less stressful on the runner's body than $\dot{V}O_2$max efforts and races,

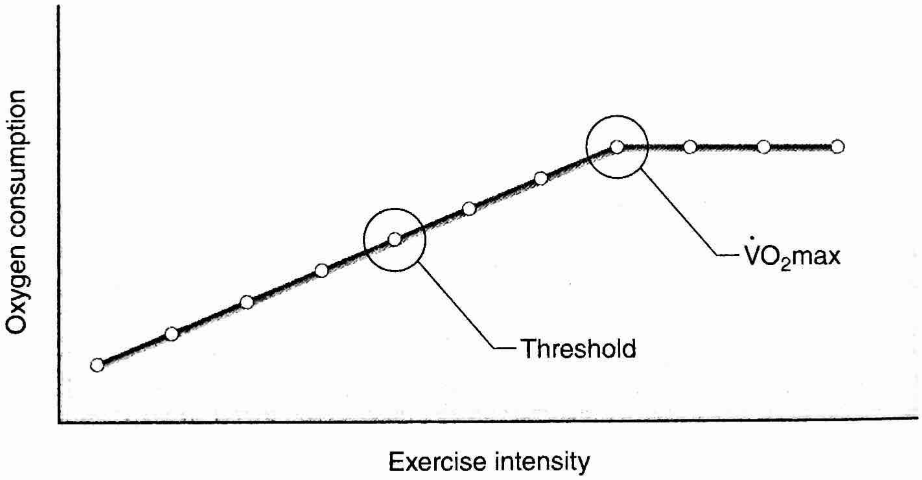

Figure 2.5 Oxygen consumption relative to exercise intensity.

threshold runs in any form (lactate threshold, tempo runs, cruise intervals, repeat miles) require longer periods of recovery than daily aerobic or recovery runs. Most nonelite runners should perform threshold-type runs no more than once a week during this phase of the training progression, and need to treat them as hard efforts. They should be preceded by an easy run plus a set of strides (faster running at 40 to 60 meters [44 to 66 yards]) the day before, and an easy or easy and long run the following day. Keep in mind that easy running still makes up the majority of this phase of training. The introduction of threshold-type training to the progression usually is the only difference from the introductory phase.

Strength training at this phase of a training progression is highly important and highly individual. The emphasis should be on countering the athlete's weakness and on functional exercises that directly correlate to running faster. For example, if a female runner lacks arm strength, an emphasis on arm exercises with lower reps (four to six) and higher weight (to exhaustion) would be called for. Also, if she was training for a 5K, functional hamstring strength would be important, so instead of performing hamstring curls, which emphasize only the hamstrings, the dumbbell Romanian deadlift and good morning exercises are more powerful exercises because they involve more of the anatomy (hamstring and glute complex) involved in the running gait. The hamstring curls should be performed in the base phase of training to develop general strength. Two strength-training workouts per week will suffice because of the intensity of the training. The muscle fibers must have a period of rest to repair themselves so they can adapt to an increasing workload.

$\dot{V}O_2$max Training

Many exercise physiologists consider $\dot{V}O_2$max and $\dot{V}O_2$max training to be the most important components of a comprehensive running program; however, this view has been challenged by some of the younger coaches who are not scientists but have had success in running and coaching. Regardless of bias, $\dot{V}O_2$max-specific workouts are a powerful training tool for improving running performance—after performing the training leading up to it.

$\dot{V}O_2$max is the peak rate of oxygen consumed during maximal or exhaustive exercise (see figure 2.5). Various tests involving exercising to exhaustion can be done to determine a $\dot{V}O_2$max score (both a raw number and an adjusted one).

Once a $\dot{V}O_2$max score is obtained, a runner can develop a training program that incorporates training at heart rate levels that equate to $\dot{V}O_2$max levels. The training efforts, or repetitions, would not necessarily end in exhaustion, although they can, but would reach the heart rate equivalent of the $\dot{V}O_2$max effort for a short period, approximately three to five minutes. The goal of this type of training is multifold. It requires the muscles incorporated to contract at such a fast pace as to be fully engaged, aiding in the neuromuscular component by placing a premium on nervous system coordination of the muscles involved in running at such a fast rate. Most important, it requires the cardiovascular and cardiorespiratory systems to work at peak efficiency to deliver oxygen-rich blood to the muscles and to remove the waste products of the glycolytic (energy-producing) process.

Training at $\dot{V}O_2max$ levels is obviously a powerful training tool because of its intense recruitment of many of the body's systems. It is important to note that a $\dot{V}O_2max$ training phase needs to be incorporated at the appropriate time in a training cycle for the runner to fully benefit from its application. Despite some athletes' reporting success by reversing the training progression and performing $\dot{V}O_2max$ workouts at the beginning of a training cycle, the most opportune time to add $\dot{V}O_2max$ training to a performance-based training plan is after a lengthy base period of easy aerobic or recovery training and a period of threshold training geared to the specific event to be completed. Rest is an important component of this phase since it aids in adaptation to the intense stimulus of the $\dot{V}O_2max$ workouts. Do not be fooled into thinking that intense workouts and multiple races without rest is an intelligent training plan. It may deliver short-term success, but ultimately will lead to injury or excessive fatigue.

The strength training performed at this stage should be a set of exercises that are highly functional and specific to the event being contested and the literal strength of the runner. For example, a marathon runner who has a strong core would focus on his or her core with multiple sets of 12 reps. The exercises are equally divided between abdominal exercises and lower back exercises to ensure balance. The emphasis is on muscular endurance. A 5K runner whose focus is speed would continue with the lower-rep, higher-weight routine of the threshold phase, emphasizing the upper legs, core, and upper torso.

Results of the Training Progression Model

As in math, each training phase builds on the by-products of the completion of the preceding phase. They are not isolated blocks, but an integrated system. For example, a completed base, or introductory, phase leads to increased capillary development, resulting in more blood volume, musculoskeletal enhancement, and, theoretically, a more efficient gait. Threshold training furthers the performance of the runner by advancing the development of the cardiothoracic systems, increasing the adaptation of the musculoskeletal system through faster muscle contractions, and heightening the body's neurological response to stimulus (faster-paced running). Anaerobic training (using oxygen already present) has little practical application to distance running, and for most non-elite runners does not factor into the training progression.

When these conditions have been met, the runner can easily begin a short course of high-intensity $\dot{V}O_2max$ training. The specifics of pace, duration, and rest are found in many training manuals, and the specific application of this type of training varies by individual. By following the strength-training recommendations for each phase of the running training progression, a runner is really preparing his or her body for the rigors of a goal race or races.

The result of following a training program based on the development of the cardiothoracic systems is better performance through an improved "engine" (the heart and lungs) and a stronger "chassis" through strength training. Whether $\dot{V}O_2max$ is determined by the exhaustion of the heart first or the muscles first, the development of the cardiothoracic systems will permit the point of exhaustion to be reached (measured in heart rate) at a faster pace and allow a greater distance to be covered. This is a visible way that improvement in performance can be measured.