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ENERGY SOURCES

When you turn the ignition key in your car, some source of fuel (gas, diesel, or fermented organic manure) must be delivered to the engine for it to fire. Even though the spark to ignite it may be there, if the fuel tank is empty, the engine will not fire. Muscles burn a substance called ***adenosine triphosphate*** (ATP) and, like a car engine, must have an ongoing supply available to continue doing work. Whenever you place a demand on the muscles to perform a task, such as turning the pedals, the energy systems must work continuously to convert energy sources into ATP to keep up with that demand.

The fuel necessary for activated muscles to contract is delivered through one of the body's two energy systems—***aerobic*** and ***anaerobic***. Energy stored in the body is converted to fuel and delivered to the working muscles through one or both of these energy systems. The energy sources that supply these energy systems are carbohydrates, fats, and, to some extent, proteins.

When you are riding, the preferred source of fuel changes as your intensity increases. At slow, easy paces, the body can burn mostly fat to produce enough energy to support muscle contractions. As you ride faster and harder, your muscles will start craving carbohydrates to keep up with the demands of a higher effort level. Carbohydrates ignite and burn much like the matches and kindling that you use to start a fire. Fats are more like the logs on the fire that burn slowly and can produce a long-lasting fuel source. Your body has a limited supply of matches to burn, so you need to learn to use them sparingly and replenish them frequently.

CARBOHYDRATES AS FUEL

Carbohydrates are a powerful but limited energy source that can be quickly converted to fuel for muscle contractions. Carbohydrates are either stored in the body within the muscles and liver or are moving around within the blood. Those stored in the liver and muscles take on a slightly different configuration called ***glycogen***. Glycogen stored in the muscles is available for rapid conversion to fuel but can be depleted quickly once you step on the gas. Muscles can develop the ability to store larger quantities of glycogen and to spare, or conserve, those carbohydrates.

The way you train plays a major role in how your muscles work and use carbohydrates. One of the main objectives of *Base Building for Cyclists* is to teach you how to train your muscles to store more carbohydrates but use less of that stored energy to perform a given task. This will make you a more fuel-efficient athlete. Efficiency is a major factor in athletic performance. One clear advantage of using fewer carbohydrates to accomplish a given effort is that you have more of this high-power energy available for when you need it most. Conserving fuel means that you can ride longer or harder when you need to. Your muscles will demand carbohydrate energy when you're chasing a breakaway, battling a headwind, climbing a tough hill, or outsprinting an angry pit bull. These are all good reasons to ration your limited supply of carbohydrates!

The small amount of carbohydrates found circulating in the blood take a form called ***glucose***. The amount of glucose in your blood is also referred to as your blood sugar level. If your blood sugar levels run low, the body will release glycogen stored in the liver to maintain appropriate glucose levels. The liver can store only a few hundred calories of carbohydrate, which will quickly become depleted, so it is best to maintain healthy blood glucose levels through ingestion and digestion of a carbohydrate source such as a sports drink or gel and water while cycling for extended or intense periods of time. The liver will also release stored glycogen into the bloodstream throughout the night while you're sleeping to maintain blood sugar levels. This means that your liver will be low or depleted of glycogen in the morning and will need to be refilled if you want to have your carbohydrate stores fully loaded to support that day's activities. The process of ingesting, digesting, and storing carbohydrates within the liver can take three to four hours; so if you have an important event that will demand a lot of carbohydrate energy, you'll want to eat a meal several hours before the start of your event. Liquid fuel sources tend to digest faster and may be a better choice for prerace meals.

Your body will have a limited total amount of carbohydrates (glycogen in the muscles and liver and glucose in the bloodstream) at any given time. The total amount depends on your state of fatigue (or recent level of physical activity), how well your body has developed its ability to store carbohydrates, and when and how much you last ate. Depending on your size, you could have from 1,500 to 2,000 calories stored when your body is at full capacity. Most of that is within your muscles. This is enough carbohydrate energy to support a high-intensity effort lasting about 60 to 90 minutes.

Carbohydrate stores must be replaced before, during, and after high-intensity or long-duration cycling activities. The depletion of carbohydrate stores is the main cause of fatigue related to longer, harder efforts, and it can also lead to the breakdown of proteins in the body. It is important to maintain carbohydrate stores in the body because they must be present in order for the body to be able to access and burn fat. When carbohydrates are broken down, they produce by-products that facilitate the use of fat for fuel. "Fat burns in a carbohydrate flame"—in other words, the body uses carbohydrates to burn fat.

The terms *hitting the wall* and *bonking* refer to the point when there is not enough carbohydrate energy left in the body to support the effort levels being demanded of the working muscles. When you run out of carbohydrates, you will need to slow down or stop because your body will be forced to begin breaking down proteins (such as muscle fibers). In effect, this cannibalizes the body for fuel. Some research indicates that your body will bonk before you totally deplete your carbohydrates. This may be a built-in protective mechanism to prevent you from running the tank completely dry.

The total amount of fuel needed from carbohydrates to support a given effort depends on several factors. In addition to how hard and long you ride, it also depends on how well you've trained your body to conserve carbohydrates. The harder you ride, the more likely you are to be using a higher percentage of carbohydrates to support the effort. Cyclists who ride hard every workout are more likely to be teaching their body to prefer carbohydrate over fat utilization.

In addition to being a limited energy source, carbohydrates also have another limitation. When carbohydrates are broken down and used as an energy source, other by-products, including lactate, are released into the bloodstream. Most cyclists are familiar with lactate. It is most commonly associated with the burning sensation that you feel in your muscles during hard efforts. More recently,

however, scientific research indicates that lactate may not be to blame for this problem. What is important here is that you realize that when you are burning carbohydrates, you are also releasing by-products into the blood that could potentially interfere with muscle contractions and force you to slow down. One of these by-products released is hydrogen ions. Research now points to these ions as being responsible for the burning sensation you feel when you are climbing a steep hill fast, riding all out in a time trial, or trying to hang on to the wheel in front of you at 30 mph. If you start burning carbohydrates too quickly and your body has not developed the ability to process the by-products fast enough, lactate levels, and consequently hydrogen ions, begin to accumulate in the blood. If you continue to push the pace, your breathing will increase rapidly and muscle contractions will become inhibited—forcing you to slow down. If you've attempted to go all out on a long climb, you've no doubt reached this point.

CARBOHYDRATES AS NUTRIENT

Carbohydrates are necessary to supply the body with energy but can also be a source of high-quality nutrition. Many athletes eat a diet that includes large quantities of carbohydrates from sources that are high in starches and refined sugars—pasta, bread, and cereal, for example. These foods can sometimes provide the extra carbohydrates necessary for recovery from challenging workouts, but making them your daily staple limits the quality of your calories. Fruits and vegetables are foods that contain carbohydrates along with large quantities of vitamins, minerals, and fiber. Your body needs these nutrients on a daily basis to maintain optimum health. It's not enough to be a fit athlete; you also have to make healthy choices for that fitness to last.

Inadequate intake of quality carbohydrates can also result in a suppressed immune system and make you more susceptible to fatigue, illness, and injury. Moreover, the brain burns blood glucose almost exclusively. This is one reason why you might feel light-headed or disoriented when your blood sugar levels get low and you bonk.

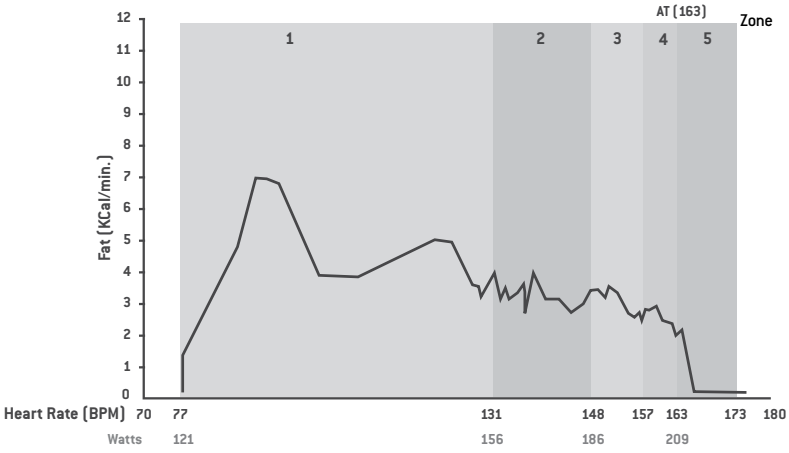
Carbohydrates should make up 45 to 60 percent of your diet, depending on which training phase you are in. During the base building phases, training emphasizes fat burning and carbohydrate intake can be at the lower end (50 percent). Your intake will need to increase in proportion to training intensity and duration.

FAT AS FUEL

Fat is a long-lasting fuel source stored throughout the body and it's available in abundant supply even in the leanest of athletes. Fat stores can support muscle contractions for long periods of easy to moderately hard efforts without any risk of being depleted. You are not likely to run out of fat! On average, an athlete may have 60,000 to 100,000 calories of fat available. Compared with the possible 2,000 calories of available carbohydrate, it is easy to see why it is preferable to train the body to burn fat. However, fat is converted to energy more slowly and cannot support faster and harder efforts in the same way that carbohydrates can. The process of converting fat to fuel requires more oxygen than carbohydrate burning does, which is one reason that you have to slow down when you run out of carbohydrates. Also, as mentioned before, for fat to be converted to fuel an ongoing supply of carbohydrate must be present. A high percentage of the body's muscles can be trained to run on, or favor, fat even at moderately high intensities. These muscles can also be trained to burn carbohydrates as the preferred fuel choice. Since there is a limited supply of carbohydrates in the body at a given time and the body can burn it faster than you can replenish it, teaching your muscles to utilize fat is the more fuel-efficient option.

If you are trying to burn fat, you should avoid spending too much time training at high intensities that demand carbohydrates. This can teach the muscles to prefer carbohydrates over fat. There is clearly a place and time in training for high-intensity efforts; but by developing your base fitness first through easy to moderate efforts, you will establish a better capacity for burning fat; which means you'll be sparing carbohydrates. By developing your utilization of fat, you begin to lay the foundation necessary to support those harder efforts that will allow you to raise your fitness ceiling. Even though there is a natural tendency toward carbohydrate burning as cycling intensity increases, you can still train in a way that will sustain fat-burning longer.

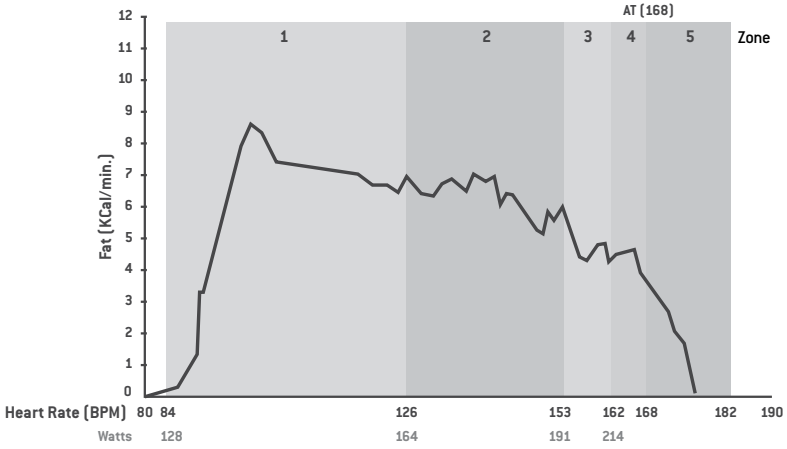
At effort levels that are easy to moderate, fat may supply as much as 70 to 90 percent of the energy being consumed. As the intensity goes up, more and more of the energy comes from carbohydrates. As effort levels near maximum, 100 percent of your energy will be coming from carbohydrate sources (see Figures 1.1a and 1.1b). When I review the fitness data for athletes, I often find that their bodies burn too much carbohydrate at even easy to moderate effort levels. In some cases they burn more than 60 percent carbohydrates at the easiest effort levels.



Calorie Utilization (KCal/min.)					
Zone	1	2	3	4	5
Fat	4.2	3.4	2.4	2.0	0

Before Base Training

FIGURE 1.1a



Calorie Utilization (KCal/min.)					
Zone	1	2	3	4	5
Fat	6.7	6.3	4.9	4.5	0

After Base Training

FIGURE 1.1b

Graphs showing how, after following the base training program outlined in this book, this athlete improved fat burning, raised the upper training threshold (or fitness ceiling), and increased power output relative to heart rate. The athlete did so by training at lower intensities than in previous base training. Although the athlete slowed down, he became faster.

These athletes typically have a history of training at high intensities frequently, and they commonly "floor it" as soon as they get on the bike, rather than warming up gradually. Once they begin a training program that emphasizes base building, their fat-burning capacity usually improves within six weeks. In turn, this causes their fitness ceiling to reach all-time highs.

Since carbohydrates are in limited supply and fat is in abundance, training to use fat and spare carbohydrate makes sense. This is one of those aspects of training that seems counterintuitive. To support your body's ability to ride harder longer, you need to teach it to spare carbohydrates. To develop your body's fat-burning ability, you need to ride at slower to moderate intensities. In other words, you have to slow down, to get faster.

If you are attempting to reduce your body fat percentage, you will also find that riding at slower to moderate intensities will lead to more success than riding hard all the time. Riding longer durations (longer than four hours) at easy to moderate intensities has also been shown to improve fat utilization as long as adequate carbohydrates are available to keep the fat fire burning.

FAT AS A NUTRIENT

Not all fat is bad for you. There are certain types of fat that should be avoided, but your body needs an adequate daily supply of the "good" fats that play a role in repairing cells and maintaining healthy tissue for strong immune and nervous systems. This topic is described more fully in Chapter 3.

Recent research has shown that a diet higher in fat can increase fat metabolism and utilization during training. For this reason, it may be worth increasing fat intake and reducing carbohydrate intake during the base-building phase. Fats can make up as much as 30 percent of your calories. The key is to consume healthy fats. A pint of ice cream a day will increase your fat intake, but it will also increase your risk of heart attack.

PROTEIN AS A NUTRIENT AND FUEL

Protein is essential for daily rebuilding of body tissues (including muscles) and blood cells and it also supports the immune system. It is clearly important for recovery, and nutritionists recommend that you include protein in your postrace or workout meals to enhance carbohydrate uptake into the muscles. Recovery

drinks are an easy way to get this protein at a ratio of about 4 to 1, carbohydrate to protein. Look for whey or egg protein powders that contain 6 grams of the branch chain amino acids (luecine, isoluecin, and valine) and glutamine.

Protein is not stored in the body and is not a preferred fuel source. As we discussed previously, if carbohydrates run low the body will eventually break down muscle tissue during extended exertion. If you are participating in ultraendurance events lasting four hours or longer, you may benefit from consuming some protein along with your carbohydrates. Over very long durations some protein will inevitably be broken down, but by periodically replacing it you may be able to delay or repair the damage. Protein should make up 25 percent of your total daily calories.

The choices you make about the foods you eat will affect your cycling as well as your overall health. Be mindful of how your body's engine uses fuel and how it uses that fuel differently when burning carbohydrates versus fat. Start paying more attention to the total amount of calories you take in and what sources they come from. After training, consume recovery foods to rebuild tissue on a daily basis, support the immune system, and replenish carbohydrate stores. The foods you eat should be high in micronutrients (vitamins and minerals). Whenever possible, it's better to choose natural foods like fruits and vegetables rather than foods that are "enriched" with micronutrients. Lean meats provide the best source for the high-quality proteins that the body needs.

Balance your macronutrients (carbohydrates, fats, and proteins) so they fall within an appropriate range. Protein should be consistently 25 percent of your total calories. Carbohydrates can make up 45 to 50 percent during base training, with healthy fats making up as much as 30 percent. After the base phase, you'll move into event-specific training and it will be time to increase the carbohydrates to 60 percent of your caloric intake to meet the higher demands of your training.