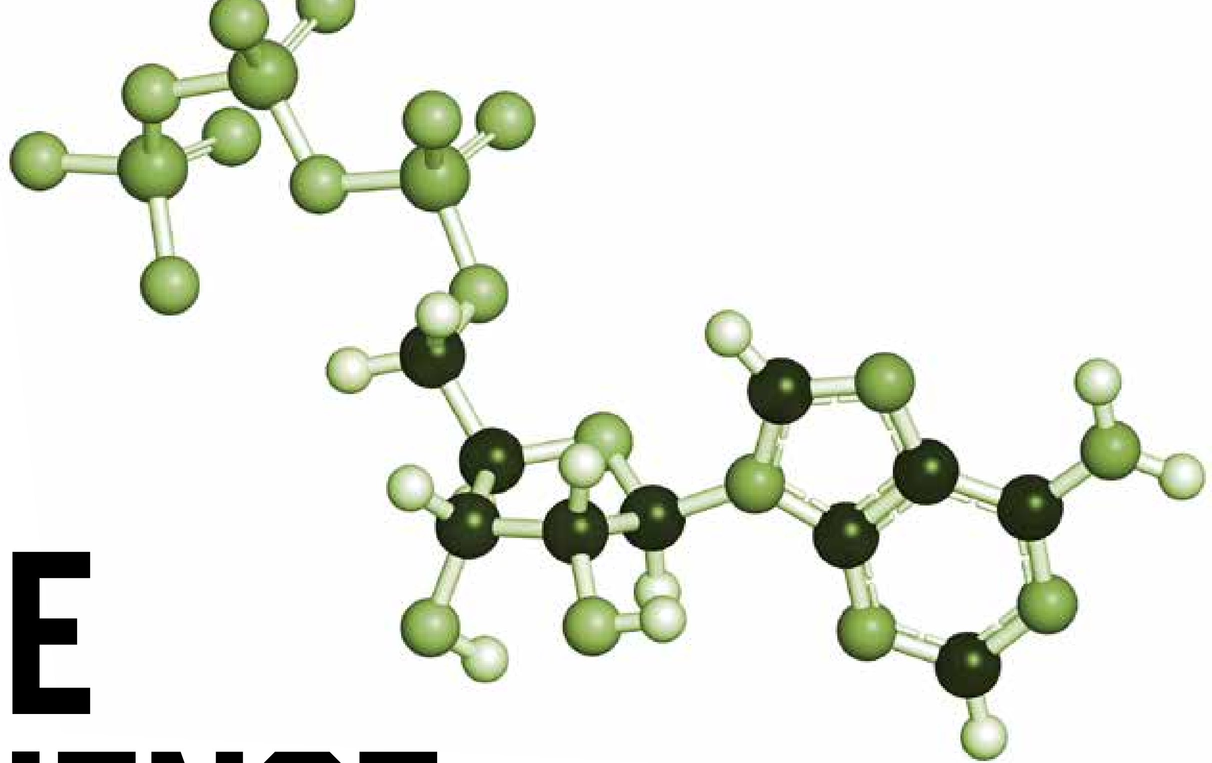

THE SCIENCE OF ENERGY

How your body turns food into fuel.

BY MAURA RHODES

Whether it's a sandwich at your desk or a five-course meal in a four-star restaurant, every morsel you put into your mouth has one key purpose: to give you energy. Without food, you wouldn't be able to sprint for a bus, lift a dumbbell or turn the pages of this magazine. Your heart wouldn't beat, your lungs wouldn't breathe and your brain wouldn't think. It really is as basic as that: Without food, your body wouldn't be able to function, any more than your car would be able to run without gas.

But while the food = energy formula sounds simple, the processes by which your body receives energy from the food you eat are anything but. Like everything our intricate human machine does, converting, say, an egg salad sandwich, into energy that keeps our body going depends upon an elegant, elaborate and ongoing series of steps that involves multiple organs, enzymes and hormones.

Is it necessary to understand all this to survive? Not really—as long as you feed your body, it will keep on keeping on. On the other hand, if you do have a basic grasp of how your body generates energy, you can use that knowledge to help boost your physical energy, mental stamina and overall vitality.

ENERGY STARS

Although you require a constant flow of energy in order to function,

Your shrimp takeout contains all the macronutrients your body needs to convert to energy: carbs, fat and protein.

you obviously can't be constantly eating. To get around this practical reality, your body converts certain components of food into forms that can be stored and drawn upon as they are needed.

Those components are known as macronutrients; they are carbohydrates, fats and protein. **Carbohydrates** provide the body's preferred form of energy—glucose, which for all intents and purposes is just sugar. There are two types: Simple carbs, which literally taste sweet, are converted almost immediately into glucose by digestive enzymes. Complex carbs, which include whole grains, starchy vegetables and such, must be broken down into glucose in a process called catabolism before they can be used for energy. That's why you might get an immediate surge of energy—the famous so-called sugar rush—after downing a candy bar but not after eating a baked potato. Any glucose that the body doesn't immediately need for energy is stored in the muscles and in the liver in a form called glycogen.

Fats are the body's energy understudies. During digestion, the fat you eat is broken down into fatty acids that are primarily used to line cells, produce hormones and help the body absorb certain vitamins. Any fatty acids not needed for this purpose are stored in fat cells throughout the body. It's only when the body runs out of glucose that it turns to this stored fat for energy. The by-products of fat metabolism are acidic chemicals called ketones.

Proteins are your body's last resort as a fuel source, but they're essential to your body functioning. Proteins are broken down into the amino acids that build and maintain muscle and other tissue and help transport nutrients throughout the body. If the body has no glycogen or fatty acids to use for energy, the liver can transform amino acids into glucose.

THE MIGHTY MOLECULE

Neither glucose nor fatty acids are used directly for energy. Both must be converted into a molecule called adenosine triphosphate, or ATP—the source of all energy at the cellular level. But your body can store little ATP, so when you need energy (which is all the time, of course), your body must synthesize it.

There are three processes by which the body synthesizes ATP; they can all be in progress at the same time to varying degrees, depending on the type of activities requiring fuel. Of these, only one is always in play, even when you aren't doing anything more energetic than scrolling through Netflix while sitting on your couch. This process, called aerobic glycolysis, involves a series of chemical reactions in which glucose and oxygen travel through the bloodstream to the mitochondria of cells, where they are converted into ATP—a process that's called cellular respiration.

More than 60 percent of the energy your body uses when you aren't physically active goes toward fueling the liver, kidneys, heart and brain.

The other two energy-generating processes do not require oxygen and are able to supply only small, short-lived amounts of ATP. When a quick burst of energy is needed—to jump-start an activity, or to fuel 30 seconds or less of high-intensity activity such as swinging a tennis racket to drive the ball over the net—a pathway called phosphagen, or ATP-PC, comes into play: This pathway produces ATP almost immediately by causing a naturally occurring chemical stored in muscles, called phosphocreatine (PC), to break apart.

For slightly longer stints of intense physical activity—a set of biceps curls, for example—enzymes in muscle cells convert the glycogen stored there into ATP. This process, which is called anaerobic glycolysis, does not require oxygen. You'll know your body has been using it when you find yourself struggling to finish the last few reps of those curls and feeling the burn in your biceps: The by-product of anaerobic glycolysis is lactic acid, which is responsible for muscle fatigue and soreness.

THE SUPPORTING CAST

Although food and oxygen are the stars of energy production, they need help from other sources. One of these is water, which is necessary for every chemical reaction that occurs in the body, including the metabolic processes involved in producing energy. Water also helps keep the body cool during exercise and is the medium in which oxygen is carried through the bloodstream to the cells.

The other sources are certain micronutrients found in foods. Especially important are many of the B vitamins, which are believed to play key roles in supporting the function of the mitochondria: B1 (thiamine), B2 (riboflavin), B3 (nicotinic acid/niacin), B5 (pantothenic acid), B6 (pyridoxine), B7 (biotin), B9 (folate/folic acid) and B12 (cobalamin).

Other micronutrients believed to be essential to energy production include vitamin C (ascorbic acid); the minerals calcium, phosphorus and magnesium; and the trace elements copper, iron, manganese, zinc and chromium. It's not entirely understood how these nutrients aid energy production, but it is known that nutritional deficiencies often result in low energy and fatigue.

Head-to-Toe Guide

HOW THE BODY USES FUEL

The brain is fueled solely by glucose, but unlike the muscles and liver, it can't store glucose and must receive a constant supply of this energy source—around 420 calories worth a day. This accounts for 60 percent of the glucose used by the entire body while at rest. The brain uses 60 to 70 percent of the glucose it receives to produce the neurotransmitters, or chemical messengers, that transmit signals from cells in the nervous system to other cells in the body in order to regulate functions like breathing, sleep, digestion and movement.

The heart is fueled mostly by fatty acids, although other energy sources play a role in keeping the beat, including glucose, ketones (a by-product of fat metabolism), lactate (a component of lactic acid) and pyruvate (a by-product of glycolysis). As you can imagine, the heart demands enormous amounts of energy.

The kidneys require enormous amounts of energy to do the job of producing urine. During this process, the kidneys reabsorb water, glucose and other materials so they aren't wasted. The kidneys also use 10 percent of the oxygen used in cellular respiration.

The liver removes two-thirds of the glucose from the blood and stores it as glycogen; when energy is needed, the liver breaks down glycogen into glucose so that it can be used where needed. The liver also regulates the metabolism of fats and proteins. Interestingly, the liver gets its own fuel not from the glycogen it stores and exports to the muscles and brain, but from by-products of amino acids.

Skeletal muscles—the ones that attach to your bones and power movement (as opposed to the cardiac muscle, which comprises the heart, and the smooth muscle that lines other organs)—get energy from three sources: glucose, fatty acids and ketones. About 75 percent of all the glycogen in the body is stored in muscle, which uses it for activity. When the body is at rest, muscles are primarily fueled by fatty acids.