Island Crabs Run Marathon: No Training, No Problem

Training for a marathon is no easy task. It takes months of preparation, not to mention cross-training and weight lifting, to get one's mind and body adequately prepared to perform the strenuous and challenging activity of running 26.2 miles. Now imagine performing this athletic feat with practically no training at all. One crustacean species does just this, only this trek usually lasts five to seven days for a total of 3.1 miles. These 12 hour per day marathons, combined with the crab's shell measuring up to 6.5" wide, would be comparable to the average marathon runner running 13 marathons or 340.6 miles over the same time frame. This event occurs on Christmas Island, which is located in the Indian Ocean, south of Indonesia. Once a year, during the beginning of the wet season (Christmas Island only has two seasons, wet and dry), usually sometime during the months of October and December, the Christmas Island Red Crabs, *Gecarcoidea natalis*, migrate from the rainforest to the ocean to mate and reproduce. The breeding activities are synched with the lunar cycles so that the low and high tides are as similar as they can be, making it easier for the females to lay their eggs.

And They're Off...

The long and arduous migration begins with the males who head out first so they can start to dig burrows in the ocean -- think of these as the hotel room. Large males make it to the ocean first in approximately five to seven days, and soon females, who have already joined the migration, outnumber them. After mating, males return inland, much more quickly than the initial journey, reaching the plateau in approximately one to two days. Females, however, stay behind until they lay up to 100,000 eggs. Once the eggs are released, they are hatched immediately, and many of the larvae are eaten by various ocean creatures. The larvae that do survive will live in the ocean for approximately one month, going through several larval stages before growing into juvenile crabs. Finally, the juvenile crabs emerge from the ocean and head inland to the plateau, usually taking nine days to complete this task.

'Tis the Season…

Red Crabs live in the moist environment of the rainforest and dig burrows that have a single entrance tunnel that leads to a single chamber where the one crab will live alone until the breeding season, which is the only time they will interact with other crabs. For much of the dry season, the crabs will retreat and primarily stay in their burrow where it is humid and cover it loosely with leaves to maintain a high level of humidity. While nestled in their burrows, the red crabs don't venture away very often. Researchers have observed that these crabs received approximately 10 minutes of exercise a day, which is quite the opposite from the aerobic activity they endure at the beginning of the wet season. “During the dry season crabs are unable to sustain even moderate exercise without supplemental ATP energy from anaerobic respiration. In contrast, the crabs migrating to the ocean showed no reliance on anaerobic respiration and had no evidence of lactic acid buildup,” according to recent research.

Overnight Muscle Overhaul

How do they get in shape for the 3.1 mile trek so quickly? To answer that question, a group of the researchers traveled to Christmas Island during the wet season and collected leg muscle samples from the crabs while they were migrating, and did so again in six months while the crabs were relatively dormant in the dry season. The researchers planned to look at the muscles at the molecular level, specifically the mRNA, so they could determine the difference between the genes being used during both seasons. "After many months [of] building a library from the mRNA molecules from both tissues and analyzing the expression levels of many genes, the team could see that there were dramatic differences between the migrating and inactive crabs' muscles," stated Kathryn Knight, the author of the summary for the researchers' published work in The Journal of Experimental Biology. She went on to say, "Not surprisingly the majority of the genes expressed in the muscles coded for muscle proteins, such as actin, which forms part of the muscle's contractile unit, and troponin and tropomyosin, which regulate muscular contraction. And, when the team took a closer look at the versions of genes that were expressed, they could see that the immobile dry season crabs' muscles were tuned to short anaerobic sprints while the muscles of crabs that migrated during the monsoon were aerobic, extremely resistant to fatigue and ideal for the crabs' arduous odyssey."Specifically, the researchers determined that there were significant differences in the abundance of 14 gene transcripts between the two samples, and it is those differences that help the crabs' muscles essentially supercharge overnight and go from the dry season anaerobic physiology to the pumped-up, high-endurance aerobic version of the wet season.

Question 1: Compare the structure and composition of red crab leg muscles between the wet season and dry season months … Explain?

Question 2: Explain what would happen if a red crab tried to run from the forest to the beach in 2-3 days during the dry season?

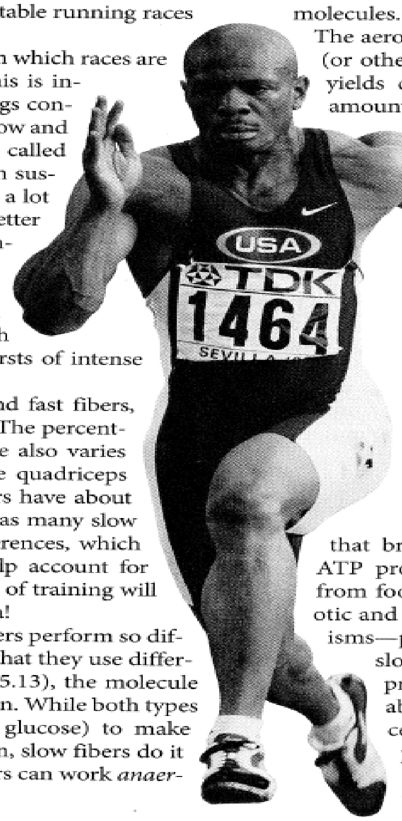
R-N-R BTR: Running-N-Respiration

How Is a Marathoner Different from a Sprinter?

Athletes who participate in track competitions usually have a favorite event in which they excel. For some runners, this event may be a sprint, a short race of only 100 or 200 m. For others, it may be a race of 1,500, 5,000, or even 10,000 m. It is unusual to find a runner who competes equally well in both 100-m and 10,000-m races; runners just seem to feel more comfortable running races of particular lengths. But why?

Could it be that runners' bodies "tell" them which races are best for them? There are indications that this is indeed the case. The muscles that move our legs contain two main types of muscle fibers, called slow and fast muscle fibers. Slow muscle fibers (also called "slow-twitch" fibers) are muscle cells that can sustain repeated contractions but don't generate a lot of quick power for the body. They perform better in endurance exercises, like long-distance running, which require slow, steady muscle activity. Fast muscle fibers ("fast-twitch" fibers) are cells that can contract more quickly and powerfully than slow fibers but fatigue much more easily; they function best for short bursts of intense activity, like weight lifting or sprinting.

All human muscles contain both slow and fast fibers, but muscles differ in the percentage of each. The percentage of each fiber type in a particular muscle also varies from person to person. For example, in the quadriceps muscles of the thigh, most marathon runners have about 80% slow fibers, whereas sprinters have half as many slow fibers and about 60% fast fibers. These differences, which are genetically determined, undoubtedly help account for our differing athletic capabilities. No amount of training will turn a marathoner into a sprinter or vice versa!



What makes these two types of muscle fibers perform so differently? An important part of the answer is that they use different processes for making ATP (see Module 5.13), the molecule that supplies the energy for muscle contraction. While both types of muscle cells break down sugar (chiefly glucose) to make chemical energy available for ATP production, slow fibers do it *aerobically*, using oxygen (O_2), while fast fibers can work *anaerobically*, without oxygen.

The structures of these two kinds of muscle cells correlate with their differing functions. Slow fibers have many mitochondria, the organelles where aerobic ATP production occurs. And slow fibers contain many molecules of myoglobin, a red protein related to hemoglobin that, like hemoglobin, is a carrier of O_2 molecules. Myoglobin helps supply mitochondria with oxygen. The aerobic harvesting of energy from sugar by muscle cells (or other cells) is called **cellular respiration.** This process yields carbon dioxide (CO_2), water (H_2O), and a large amount of ATP—perfect for sustaining muscle contractions over a long period of time.

Fast muscle fibers, on the other hand, are thicker than slow ones, have fewer mitochondria, and have much less myoglobin. The thickness of fast fibers enhances their power. But they rapidly deplete their oxygen supply and switch to an energy-harvesting process that produces much less ATP per glucose molecule. Thus, they can't completely break down glucose to CO_2. Instead, they produce lactic acid, which lowers the pH in muscles, making them ache and fatigue. Fast muscle fibers are best at supplying short bursts of power. Anaerobic ATP production in our muscles is only effective for a minute or so.

Muscle cells are not the only cells in our body that break down sugars and other food molecules for ATP production. All our cells harvest chemical energy from food, as do the cells of all other organisms, eukaryotic and prokaryotic alike. Cells of most eukaryotic organisms—protists, fungi, plants, and animals— function like slow muscle fibers in that they carry out the aerobic process of cellular respiration. Before learning more about how cellular respiration powers the work of cells, let's take a step back and consider the bigger picture of energy flow through an ecosystem. In other words, where does the energy for cellular work originate? ■ ■ ■

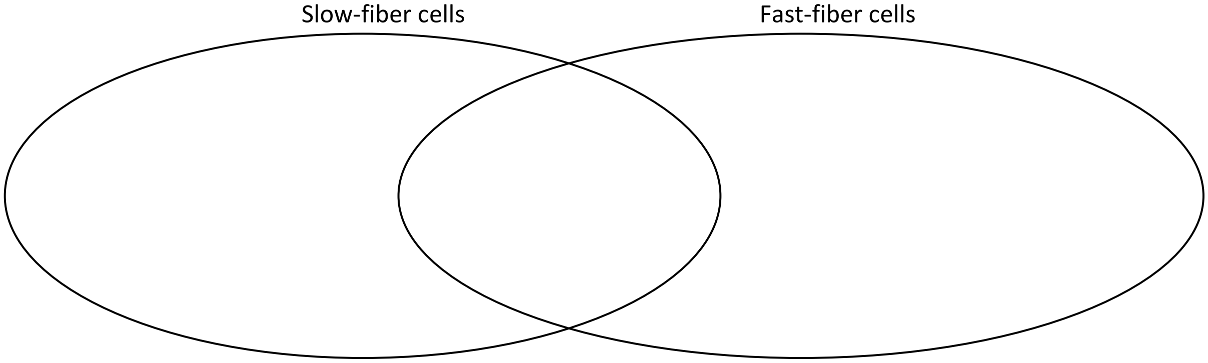
Question 1: Compare the percentage of fast and slow fibers in the thigh muscles of sprinters vs marathon runners

	Fast-fiber %	Slow-fiber %
Sprinter		
Marathon runner		

Question 2: What causes the differences in slow vs fast muscle fibers from person to person?

Question 3: Compare muscle cells full of slow vs fast fibers in the Venn diagram below:

Slow-fiber cells Fast-fiber cells



Question 4: Predict what would happen if an Olympic marathon runner switched and began to train to as a sprinter … how competitive do you think they would be …. WHY?