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FREAKS OF NATURE?

Ultraendurance racers torture their bodies and minds to achieve near-impossible physical feats. Is it an exceptional genetic make-up or the vestiges of human evolution? **Helen Pearson** reports.

Trek 125 kilometres, and cycle 250 more. Kayak 131, rappel through canyons for another 97, and swim 13 in churning whitewater. Throw in some horseback riding and rock climbing; spread it all over six days in the blistering Utah heat; and never stop to sleep.

That's the punishing formula for the annual Primal Quest adventure race, considered one of the most extreme tests of human endurance. Of the 90 four-person teams that competed this summer, only 28 finished the course. "It was more like adventure torture," says Michael Tobin of the winning team.

Yet a growing number of athletes are opting to push the outer limits of their body's abilities. If a marathon or Ironman triathlon isn't enough, athletes can enter 'extreme ultraendurance' events, which spread the agony over several days (see 'The toughest races on Earth'). And alongside the racers — figuratively and sometimes literally — are exercise physiologists.

Researchers see these radical events as a testbed for ideas on how some people manage to perform physical feats at which others can only marvel. Some scientists argue that ultraendurance athletes have special genes or physiology that allow them to perform beyond ordinary limits. Others claim that these athletes are little different physically from fit people such as marathon runners — but have something unique about their brains that allows them to keep exercising when the body screams 'stop'. Either way, many find it hard to resist the opportunity to study human physiology as it is stretched towards breaking point. "Scientists are naturally drawn to the extreme," says Euan Ashley, a cardiologist at Stanford University in California who has studied the genetics of endurance racers.

Yet much of the research is still in its infancy. Most of the focus in exercise physiology remains on prestigious professional and Olympic sports, not the protracted and gruelling competitions of amateurs. In addition, ultraendurance is difficult to study in the lab because few subjects are willing to run on a treadmill for 24 hours or more.

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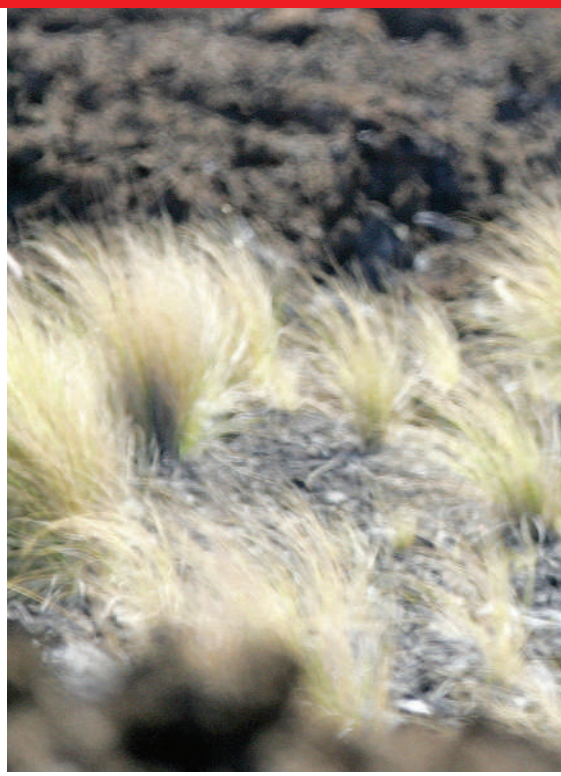
But some key differences between ultraendurance athletes and other athletes are beginning to emerge. For instance, short races, such as 10-kilometre competitions, are usually won by athletes in their 20s. But ultraendurance races tend to be won by people in their early to mid-30s — because the body takes a longer lifetime of training to achieve the toughness of muscle and efficiency of metabolism that such a race demands, experts say. Ultraendurance winners also are good at performing for sustained periods of time at 60–70% of their maximum output. The strongest conventional athletes, by contrast, are those who use oxygen most efficiently when working at close to 100% of their maximum.

Pushing the limits

Additional insights are starting to come from studies led by Mikael Mattson and Jonas Enqvist, researchers at the Karolinska Institute in Stockholm, Sweden. Their team had nine world-class racers run, cycle and kayak on lab machines nonstop for 24 hours while the researchers recorded various measures of heart function and metabolism. The group is still analysing the data, but one preliminary result suggests that ultraendurance exercise makes the energy-generating mitochondria in the athletes' muscles more efficient at using fat rather than glucose as fuel.

Fat generates more energy than glucose per kilogram, but the body can't normally burn fat when exercising very hard. The bodies of endurance racers may have found a way to go faster using fat as fuel, saving stores of glucose for later on in the race. "It's one reason these athletes are physiologically different from other athletes," Mattson says. He calculates that the athletes burned around 20,000 kilocalories (84,000 kilojoules) during the day of exercise — an amount almost impossible to replenish by eating.

What is not clear from Mattson's work is whether the ultraendurance athletes were born with special physiological abilities or whether they gained them through training. But genes probably play at least some part, according to studies of more than 400 participants in the South African Ironman competition.



Energetic mutation: are Ironman world champions, such as 2005 winner Faris Al Sultan above, endowed with endurance genes?

A team led by Malcolm Collins, a molecular biologist at the University of Cape Town, has examined the gene that makes angiotensin-converting enzyme (ACE), a peptide that helps narrow blood vessels. In a separate study, one form of this gene had already been found to be associated with endurance performance in mountaineers and army recruits[1]. More recently, Collins' group found that more than 77% of the fastest South African-born Ironman triathletes carried one or two copies of this endurance variant, compared with 67% of non-athletes[2]. The effect didn't hold for non-South African athletes, but it triggered Collins to start looking at other potential gene variants that could affect Ironman performance.

In particular, he is now scrutinizing two genes that work along the same biochemical pathways as ACE. Variants of these genes affect the blood flow and metabolic efficiency of muscles: one makes a receptor for a peptide called bradykinin, and the other makes an enzyme called nitric oxide synthase 3. The researchers found that athletes with a particular combination of 'fitness' variants of these two genes finished the Ironman in 12 hours 30 minutes, on average, compared with 13 hours 4 minutes among those who carried the 'slow' variants[3].

Tim Noakes, a sports physiologist who works with Collins at the University of Cape Town, argues that the bodies of ultraendurance athletes are actually little different from those of other sports people. The brain, he says, is the oft-overlooked organ that sets ultraracers

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apart. These people "are mental freaks", he says, not physiological ones.

Conventional thinking in exercise physiology holds that the muscles, lungs and cardiovascular system set the limits of performance. But the brain coordinates biochemical signals from these peripheral organs, such as those indicating fatigue and tissue damage, and will unconsciously stop us before we wreck our bodies. Perhaps, Noakes suggests, ultraendurance athletes have brains that allow them to override warning signals that would bring others to their knees.

Noakes is now examining what conscious and unconscious information the brain uses to set the ideal exercise pace. In one recent study, he and his colleagues showed that athletes use oxygen more economically and feel less exertion if they know the length of time they will be running, compared with those deceived about the time but who run at exactly the same pace[4].

But even couch potatoes may have something of the endurance racer in them. Daniel Lieberman, a biological anthropologist at Harvard University in Cambridge, Massachusetts, argues that the human body is well-adapted to long-distance running, as an evolutionary hangover from our hunting and scavenging days[5]. Ultraendurance racers "are able to be freaks because evolution has enabled us", he says. A body capable of jogging tens of kilometres at a time helped our ancestors survive, he says. Fuelled by plentiful water, energy bars and yet more training, that body can complete the 90 or more kilometres of an ultramarathon.

"The brain is the oft-overlooked organ that sets ultraracers apart — they are mental freaks, not physiological ones."

If this is true, then many of those who study ultraendurance racers have also embraced their evolutionary past. Paul Laursen, for instance, was kicked out of kinesiology studies at Simon Fraser University in British Columbia, Canada, after becoming so absorbed in triathlon competitions that he flunked his first year. Now he has a remarkably lean 10.6% body fat, a 48-beat resting heart rate and, in early December, swallowed a miniature thermometer and ran an Ironman in Western Australia as the subject of his own study into muscle damage. He ran a worse time than any of his previous Ironmans — but says the experiment was a success. ■

Helen Pearson is a reporter for *Nature* in New York.

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The toughest races on Earth

Robyn Benincasa, a San Diego firefighter and successful ultraendurance athlete, remembers her most gruelling moment. In the Ecuadorian Andes in 1998, she had been racing for two days and nights without sleep, and faced climbing a volcano more than 6,000 metres in altitude. "My nail beds were blue, my lips were blue, my whole body was blue," she recalls. "I was on my hands and knees in the snow, crying." Somehow — she does not remember how — she made it to the summit, and her team eventually won.

Sound like a good time? People voluntarily participate in such races, looking to push their bodies to the limit. Here's a look at some of the most challenging:

Race Across America
A non-stop bike race that spans the United States. Deprived of sleep, competitors cover more distance than the Tour de France in about 40% of the time.

Badwater Ultramarathon
A 215-kilometre foot race, billed as the world's toughest, that starts 85 metres below sea level in California's Death Valley and goes to around 2,500 metres at Mount Whitney. Temperatures can reach 55 °C. The current male record holder took 24 hours, 36 minutes to finish.

Hawaii Ironman Triathlon
The world championship of Ironmans spans a 3.9-kilometre swim, a 180-kilometre bike ride and a 42-kilometre run. Participants win a spot in qualifying Ironman races around the world.

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Marathon des Sables
A week-long, 240-kilometre ultramarathon in the Moroccan desert. Competitors carry their own food and gear.

Primal Quest Expedition Adventure Race
The biggest, and most publicized, adventure race. Teams of four trek, cycle, paddle, navigate, climb, canyon and otherwise cover roughly 700 kilometres in a quest for a prize worth US$250,000 in 2006. **H.P.**

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