ENDURANCE

EVOLUTION OF ENDURANCE ATHLETES

What’s the difference between a couch potato and a marathon runner? It’s partly that the marathoner actually gets off the couch and runs, training him or herself to become a better runner. However, physiologists know that being a good athlete also depends on genes. Genetics can contribute up to half of the variation seen in human exercise capacity, and some other species have evolved the ability to perform amazing feats of athleticism, often with very little training. It is because exercise capacity has a genetic basis that it can evolve, and can confer a strong advantage to animals in the wild. To investigate further, Norberto Gonzalez from the University of Kansas and his colleagues focus in a recent paper on the evolution of running endurance in rats.

Transporting oxygen to mitochondria in exercising muscles is extremely important for making energy in the form of ATP. Animals with greater exercise capacity are generally better at transporting O2 along the pathway from environment to mitochondria, and this pathway has many steps: O2 is brought into the lungs with each breath, where it diffuses into the blood and is delivered throughout the body, then finally diffuses to mitochondria in the tissues. It was unclear how each step of the O2 transport pathway evolves in athletic species, which led Gonzalez and his team to find out more by artificially selecting rats for running endurance.

Artificial selection is a way of mimicking natural selection in the lab. Every generation, individual rats with the best running endurance were selected and bred together, generating high endurance populations that could run much further than rats with low running endurance. To understand the basis for these differences, Gonzalez and colleagues first measured the maximal rate of oxygen consumption (VO2max) during heavy exercise in rats after 15 generations of selective breeding. They found that the high endurance runners had a higher VO2max than rats in earlier generations, so they knew that the oxygen transport pathway was evolving. To find out what was causing the changes in VO2max, the authors analyzed each individual step in the O2 pathway. Both the rate of O2 delivery to the tissues by the blood and rate of O2 diffusion into the tissues from the blood were enhanced in high endurance runners, which explained their higher VO2max. All other steps in the O2 pathway were the same in high and low endurance runners.

Gonzalez and colleagues made a remarkable finding when they compared these results to experiments in the same lines of rats after only seven generations of artificial selection: at this early stage of evolution, only the rates of O2 diffusion into the tissues were enhanced in high capacity runners. This discovery has important implications for how physiological systems evolve. It implies that when selection is applied to the O2 transport pathway as a whole, different components of that pathway each evolve at a different pace. The authors conclude that the changes observed in tissue O2 diffusion at generation seven promoted changes in O2 delivery at generation 15. In more general terms, evolution of the first physiological trait increased the selective advantage of the second trait, which later evolved as well. Gonzalez and colleagues have therefore shown us that the evolution of endurance capacity involves multiple physiological changes, and that there are many interesting differences between couch potatoes and marathon runners!


Graham Scott University of British Columbia scott@zoology.ubc.ca

NAKED CARP TAKE A SALTY HOLIDAY

Like tourists going on holiday to the Dead Sea, endangered naked carp (Gymnocypris przewalskii) migrate annually between freshwater rivers where they spawn, and salty Lake Qinghai, where they take a break to feed and grow. Lake Qinghai, the largest lake in China, is located over 3000 m above sea level, but may soon become a toxic destination for the carp. The lake is continuously drying up and becoming ever more saline. Diversion of water for agriculture as well as climate change have led to a decline of the lake’s water levels by about 10–12 cm per year during the past 50 years. With these problems in mind, Chris Wood from McMaster University, Ontario, and his eight collaborators from Canada and China were interested in how naked carp, a very sensitive, slow growing species which feeds on plankton, adapts to living in the saline lake’s harsh environment.

To have a closer look how the fish cope with living in such salty waters, the international team measured the fishes’ metabolism, water balance and excretion, both on-site in China and in the lab in Canada. To find out how the carp’s metabolism was affected, they transferred fish from fresh river water to salty Lake Qinghai water and observed that naked carp also take a metabolic holiday in the salty lake water. In the first 36–48 h after the transfer, Wood and his team saw that naked carp’s oxygen consumption was reduced to 60% of the oxygen uptake seen in carp kept in river water. This change reduces the carp’s energy demands by 40% while they are in lake water.

Switching their attention to the effect of the transfer between river and lake water on water balance and excretion, they measured the function of the gill and kidneys, by looking at the activity levels of

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