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Low daily energy expenditure enables giant pandas to survive on bamboo

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Giant pandas (*Ailuropoda melanoleuca*) belong to the bear family (Urisidae) within the order Carnivora and specialize on a diet of bamboo, but still retain a typical carnivoran gastrointestinal tract. Consequently, they have a very low energy digestive efficiency (9.5%–34%) if fed only bamboo in captivity. The property of metabolic physiology of giant pandas is an interesting question. McNab [1] wrote in his new book *Extreme Measures* that "basal metabolic rate (BMR) of the giant panda, a semi-arboreal, bamboo-eating bear, has not been measured, but given its habits, it undoubtedly has a BMR that is appreciably less than expected from (body) mass. Its basal rate is possibly similar to, or less than, that found in the sloth bear (*Melursus ursinus*), which feeds heavily on termites and has a basal rate equal to 80% (of expected). The sloth bear, and presumably the giant panda, differ in energetics from other bears such as omnivorous black (*Ursus americanus*) and brown bears (*Ursus arctos*), and strictly carnivorous polar bears". Because of their special position in both conservation and culture, the physiology of giant pandas is no doubt of interest to many animal physiologists. Surprisingly there are no available data about their basal metabolism, although several papers stated their special digestive physiological function, such as the ability to digest fiber [2], but the role of gut microbiota is still unclear. It has been found that the gut microbiota of giant panda and red panda (*Ailurus fulgens*, also carnivorous but eating bamboo), diverged rather than converged based on the same diet, and the bacterial taxa between giant and red pandas are different [3].

Scientists have long speculated that to survive on bamboo, which is such a low quality food, giant pandas should have a low rate of metabolism. It has been reported, by using remote radar technology to get heart rate, which is often closely related to oxygen consumption, that giant pandas might exhibit hypometabolism during sleep for energy conservation. Giant pandas have heart rates lower than captive black bears and brown bears during a time of seasonal lethargy after adjustment for body mass. According to calculated levels of metabolic depression, giant pandas lower metabolism on a daily basis to levels similar to those of black and brown bears during their seasonal lethargy [4]. McNab [5] has measured the basal rate of the red panda and found that their basal rate was equal to 49% of the value expected from mass, which undoubtedly reflects its bamboo diet and possibly its arboreal habits. He estimated the basal rate of giant pandas according to the equation for 62 carnivorans that the expected basal rate is 59% of the value expected from body mass for a giant panda with body mass of 120 kg.

Recently in a collaboration between scientists from the Institute of Zoology and the Institute of Genetics and Developmental Biology of the Chinese Academy of Sciences, and Beijing Zoo, new findings and advances on the energetics and physiology of giant pandas were published in *Science* [6]. They applied the doubly-labelled water method to measure the daily energy expenditure (DEE) of five captive pandas and three wild pandas. Results showed that pandas have substantially lower DEE than almost all other

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mammals after correction for their body weight, which is 38% of the predicted values of the mammals (45% for wild pandas).

They tried to give the reasons to explain the low DEE from several aspects including anatomical, behavioural, physiological, and even genetical factors. Giant pandas can achieve this exceptionally low expenditure in part by reduced sizes of several vital organs and low physical activities. By using historical autopsy data they found that pandas have small vital organs such as brain, liver and kidneys which can make great contributions to BMR, for their body size. Their brains are 82% of the expected size, kidneys 75% and livers 63% of the expected size. Minimizing the time spent in and intensity of physical activity can also contribute to reducing DEE. They obtained the activity data for captive pandas by direct observation and by using global positioning system (GPS) and direct observations for wild pandas. In captivity, the pandas spent 33% of their time in physical activity, and in the wild 49% of their time was devoted to physical activity. For wild pandas, the mean movement speed was only 26.9 m per hour. Giant pandas maintain high body temperature and do not engage in torpor or hibernation. They proposed that pandas have a deep pelage able to trap their meagre body heat. Supporting this idea the lateral surface temperatures of pandas are significantly lower than those of zebras, dairy cattle and domestic dogs. Circulating levels of thyroid hormones thyroxine (T4) and triiodothyronine (T3) averaged 46.9% and 64% respectively of the levels expected for a eutherian mammal based on their body size. After comparing the panda genome with the genomes of five other carnivorans, as well as mouse and human, they found a unique variation in the dual oxidase two gene (*DUOX2*) in the panda which results in a premature stop protein and probably a truncated non-functional protein. *DUOX2* encodes a transmembrane protein that catalyzes the conversion of water to hydrogen peroxide, which is used in the final step of T4 to T3 synthesis. From their study and interpretation, we can see a suite of morphological, behavioral, physiological, and genetic adaptations, leading to the low energy expenditure, which likely enables giant pandas to survive on a bamboo diet. This is a nice integrative research on animal conservation and zoology.

Although scientists have studied extensively on the biology, behavior and conservation of giant pandas, we still need more new information about their physiology, ecology and evolution. It has been shown in other species that BMR is positively related to DEE or sustainable maximum energy intake rate: the higher BMR, the higher DEE or sustainable energy intake. Therefore trying to measure the BMR is necessary to fully understand the thermoregulatory physiology of giant pandas. It would be useful to establish the relationship between thyroid hormones and BMR. One possibility would be a manipulation experiment such as adding thyroid hormones in the food or drink and see the changes in BMR, DEE or food intake, which would be helpful to clarify the roles of thyroid hormones. Further, it has been predicted that species with high BMR (mass-independent) probably showed more competitive and high population numbers. If this applied to giant pandas, is there a possibility that low BMR is one of the reasons to constrain population increase in wild pandas? We are also interested in the questions such as the population energy use of wild pandas and, as carnivores, what is their ecological role and how they interact with other species within the community. Size of organs contributes to the changes in body size. They suggested that small organ size is a reason to decrease DEE. Giant pandas live in mountain areas in nature, and the reproductive season is relatively cold. We can predict that small body size can increase thermal conductance (mass-specific). Low ambient temperature can increase the cost of living for giant pandas. Further, organ or tissue metabolic properties of mitochondria (if there are opportunities to measure), such as mitochondria protein contents and cytochrome c oxidase activity, can provide a more comprehensive message. Finally, global warming can affect the growth of bamboo and consequently the life of cool giant pandas physiologically. More data are needed for understanding the effect of global warming on their physiological functions, behaviors, and geographic distribution. Many questions and mechanisms about giant panda physiology are still waiting for answers. New approaches of conservation physiology may help get new information, especially for wild pandas.

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