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Biology A (Salters Nuffield)

Advanced

PAPER 3: General and Practical Applications in Biology

Scientific article for use with Question 8

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Pearson

LIFE IN THE SLOTH LANE

Once defamed as slow and stupid, sloths are now recognised as masterworks of mammalian evolution – and we could all learn from their energy-saving tricks.

Sloths' exquisite adaptations have allowed them to survive for 30 million years.

Jonathan Ross ISTOCK PHOTO

1. GEORGES-LOUIS LECLERC, the Comte de Buffon, was the most famous naturalist on the planet in the middle of the 18th century, and he didn't think much of the New World. He proclaimed the Americas "degenerate", a sodden, miserable land filled with weak and inferior species. But Buffon reserved his most biting contempt for one creature in particular.

2. He wrote of their "too short" and "badly terminated" legs, of their "slowness, stupidity... and even habitual sadness". "These sloths," he continued, "are the lowest term of existence in the order of animals with flesh and blood. One more defect would have made their existence impossible."

3. Buffon couldn't have been more wrong. What he saw as shortcomings we now realise are exquisite adaptations that have allowed sloths to thrive in an exceedingly austere niche for at least 30 million years. In fact, the closer we look at sloth biology, the more we see just how hard evolution has had to work so that these notorious dawdlers can take it easy.

Box 1

Sloths are included, along with the armadillos and anteaters, in the Order Xenarthra (Edentata). Analysis of amino acid sequences of the eye lens proteins has confirmed earlier anatomical evidence indicating that the xenarthrans are an old offshoot of the eutherian stem that arose at least 75–80 million years ago. Initially all present-day sloths were considered to belong to the family Bradypodidae with two genera, Bradypus and Choloepus. However, a new classification has been proposed, which places the two-toed sloths in the family Megalonychidae and the three-toed sloths in the family Bradypodidae. It is thus now generally believed that the two living families of sloths have quite different phylogenetic origins and that Bradypus is derived from megatheroid and Choloepus from megalonychid sloths, their separate evolution beginning about 35 million years ago in the late Oligocene.

4. One reason we know so little about sloths is that they are surprisingly difficult to study. They live high in the canopies of South and Central America and are extremely hard to spot: they are small, they rarely move and their fur often gets matted with green algae, making them blend in with the leaves.

Box 2

Algae representing four phyla have been cultured from Bradypus, these being Chlorophyta, Chrysophyta, Cyanophyta and Rhodophyta.

During the dry season the hair of the sloths usually has a dirty brown coloration, but during long periods of rain it may show a very appreciable greenish tinge brought about by the increased presence of symbiotic algae. According to Britton, the algae may already be present in the hair of animals only a few weeks old and it has been suggested that they provide camouflage for the sloths, while obtaining shelter for themselves. Aiello discussed the different possibilities as to why sloth hair has evolved in such a way to encourage algal colonization. She does not believe that camouflage or thermal insulation are the only or necessarily the more important reasons and suggested that the algae may provide nutrition or a particular trace element. Lack of healthy algal colonies could thus provide an explanation why Bradypus does not survive long in captivity.

5. To figure out exactly how slow they are, in 2014, Jonathan Pauli at the University of Wisconsin-Madison and his colleagues went to Costa Rica to measure the metabolic rates of three-toed brown-throated sloths and Hoffmann's two-toed sloths. They found that while both species have extremely slow metabolisms, the three-toed sloth is a record-breaker. The rate at which it expends energy in the wild, known as the field metabolic rate, came in at 162 kilojoules per day per kilogram, meaning it has lower energy needs than any other mammal that isn't hibernating, including renowned slouches like koalas (410 kJ/day/kg) and giant pandas (185 kJ/day/kg).

Box 3

Seymour has reviewed the role of sloths as the possible hosts to a whole variety of arthropod-borne viruses (arboviruses), citing work carried out in Belém (Brazil), and in Panama. However, whether or not sloths are essential or only incidental to the natural cycle of an arbovirus, their long experimental viremias are remarkable and Seymour suggests that these may be due to the animal's low metabolic rate.

Seymour finally concluded that the wide variety of arboviruses isolated from sloths can be characterized according to antibody and virus isolation data as being sloth specific (Utinga, Utive and Changuinola viruses), incidental in sloths (such as the Venezuelan encephalitis viruses), or others (including the St. Louis encephalitis and Oropouche viruses) for which the role sloths play in the natural cycles is as yet uncertain. Simultaneous productive infections appear to be possible in these animals.

6. Part of the reason sloths are such extreme energy savers is their diet. They are arboreal folivores, meaning they live in trees and eat leaves. It is a deeply unpopular lifestyle choice, occurring in just 0.2 per cent of mammal species, and for good reason; leaves tend to be rather difficult to digest and contain few nutrients. Some tree-living leaf-eaters, such as howler monkeys, get around this by gorging on massive quantities of the stuff.

7. Sloths have adopted a different strategy: they nibble a bit here and there, making sure to keep their stomachs full. And they don't rush digestion. It can take anywhere from two days to nearly two months before swallowed food emerges again as dung, which makes this the longest digestive process on record for a plant-eating mammal. That is particularly weird when you consider that among mammals, the digestion rate typically depends on body size, with big animals taking longer to digest their food.

8. A long and winding alimentary canal isn't the only way sloths conserve energy. They also allow their body temperature to vary wildly compared with other mammals. Whereas humans hover within a degree of 38 °C, the three-toed sloths Pauli studied allowed swings of nearly 5 °C as the forest cooled or warmed around them. That saves a lot of energy, because maintaining a core body temperature is energetically expensive.

9. But sloths still need a way to warm up. Shivering, favoured by most warm-blooded animals, is for creatures with energy to burn. Instead, three-toed sloths climb higher into the canopy each morning to make the most of the sun's generosity. Sloths also can't jump.

10. But even beyond saving energy, the sloth's characteristic slow-motion upside-down walking might have another benefit: camouflage. One of the sloth's main predators, the harpy eagle, relies on seeing its prey move. Hanging upside down, completely still, for hours on end seems to do the trick. Sloths can do this in part thanks to their long, curved claws, which their giant ancestors used to excavate tunnels, but now operate more like coat hangers. The constant grip is made possible by a lattice of tendons in the hands and feet that draw the digits closed while at rest.

11. But there seems to be more to their muscular abilities than that. We usually think about muscles as doing one thing well, says Michael Butcher, a zoologist at Youngstown State University in Ohio. An Olympic weightlifter, for instance, has muscles capable of small, powerful movements, whereas a marathon runner's muscles are geared towards sustaining long periods of exertion. "But sloths break that rule," he says. They have an uncanny ability to resist fatigue, as well as a surprising amount of strength.

12. To better understand how they do it, Butcher dissected a dozen sloth cadavers. He was surprised to see they had very little muscle tissue – roughly 10 per cent less than you find in other arboreal mammals. But what muscle there is appears to be extraordinary. Most strikingly, sloth muscles seem to contain a unique set of enzymes that confers tolerance to heavy accumulations of lactic acid, which may help them resist fatigue as they hang out or move in super-slow motion.

Box 4

Sloths act as hosts to a wide variety of arthropods, which include biting and bloodsucking flies such as mosquitoes and sandflies, triatomine bugs, lice, ticks and mites. Sloths also carry a highly specific community of commensal beetles, mites and moths.

It has been suggested that the sloth moths may receive some protection from avian predators and possibly find nutrients in secretions of the sloth's skin and/or the algae present on the fur. Waage and Best reported that some three-toed sloths may carry in excess of 120 moths; lower numbers may occasionally be seen on two-toed sloths. They also pointed out that there is considerable sympatry amongst moth species found on sloths and that several different species may coexist on the same animal.

13. For all these fresh insights, there is still a lot to learn about sloths. We don't know why they climb all the way down to the forest floor to defecate, for instance, never mind why they bury the mess. It doesn't seem very frugal.

14. One thing is clear, though: the more we learn about these extraordinary creatures and their unhurried lifestyle, the easier it is to appreciate how diet and metabolism can drive evolutionary adaptation.

T4·4 natural selection

T4·3 adaptation

T1·7 diet?

↳ T7·3, 7·4, 7·5 respiration

T5·17, 18, 19

ns, evidence for evolution + speciation

Adapted from:

New Scientist, Essential Guide No.11, Life on Earth: 69-70

the Brazilian Journal of Medical and Biological Research, (2000) 33: 129-146 and (2001) 34: 9-25.