Creating the Nation's first BioPark

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Letter from the Desk of David Challinor
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The trees in the new Amazonia exhibit were lowered through the roof and transplanted about eight months ago; since then the canopy under the glass dome has started to close. The exhibit is now even beginning to smell like a tropical forest, and its success in not only attracting but also educating visitors has been a great reward to its planners under the imaginative direction of Mike Robinson. The closing canopy of the exhibit serves as an artificial microcosm of a real one and helps us to understand the complex interactions that occur there.

The canopy of an unlogged tropical rain forest is closed throughout the year, which means that canopy trees must replace their foliage faster than their leaves are consumed by folivores (leaf-eaters). To protect their foliage for photosynthesis, trees have evolved leaves that generally become increasingly unpalatable as they age, but this does not prevent hoards of leaf eaters, mostly invertebrates (caterpillars, leaf miners, etc.), from reaching the canopy to feed. Since most of the nutrients in tropical rain forests are found in the fruit and leaves of the canopy, some novel arboreal (tree-dwelling) folivores have evolved to exploit this rich source of food. There are three unusual vertebrate leaf eaters of the New World rain forest: the sloth (mammal) and the green iguana (reptile), both of which are on display in Amazonia, and the hoatzin (bird). These three animals illustrate the point that despite the seeming abundance of leaves these vertebrates have to eat, the offsetting cost to them to use this food source is great: all three have to conserve energy.

There are two kinds of sloth: the three-toed (*Bradypus variegatus*) and the two-toed (*Choloepus hoffmanni*), both of which live in the canopy and sometimes even share the same tree. The three-toed sloth is the one on exhibit in Amazonia, and our concern here is the cost to this mammal of maintaining a diet almost exclusively of leaves.

Mature leaves are tough and can only be digested with the help of bacteria that live in the gut of these sloths. Bacteria, although efficient decomposers, break down leaf particles slowly, requiring the consumed leaves to spend enough time inside the sloth for the bacteria to work. The warmer the stomach, the faster the bacteria operate, so sloths often stay motionless high in the canopy to expose themselves to direct sunlight to raise their body temperature. Cold nights followed by many rainy days

can slow digestion to the point where a sloth can die of starvation with a full stomach. By carefully observing radio-collared sloths, scientists have learned that they descend to the ground to defecate only once every six to eight days. For reasons still unknown, the three-toed sloth digs a small depression with its stumpy tail into which it deposits its dung. The rate (about a week) at which food passes through the sloth's digestive tract is certainly the slowest for any mammal, and is about the same or even slower than for a tortoise.

The advantage of abundant canopy leaves enjoyed by sloths is not as great as first appears because the sloth must choose the leaves of those trees that are most digestible and nutritional. The trees with highly palatable leaves are generally widely scattered, which obliges the slow moving sloth to keep hunting for appropriate trees to sustain itself. Thus to survive in the apparent midst of plenty, the sloth must move slowly for several reasons: to save energy, to slow digestion to give bacteria time to break down leaves, and to stay still near the top of the canopy to keep its body temperature high enough to insure its elaborate digestive mechanism functions properly.

If leaf-eating mammals are relatively uncommon, foliverous birds are rare. In the canopies of mangrove swamps and low lying riparian trees of the Orinoco and Amazon basins lives the hoatzin, a crow-sized bird of the cuckoo family (Opisthocomus hoazin). This ungainly bird flies poorly and seems to use its wings primarily to balance itself as it flops from branch to branch. It gorges itself on leaves early in the morning and, like sloths, spends mid-day resting and keeping warm to enable the bacteria in its enlarged muscular crop and lower esophagus to break down its leafy diet. Birds cannot chew, so the crops of seed-eating birds often contain small pebbles to help break down hard-coated seeds before they enter their stomachs. The hoatzin's crop, however, has evolved into a large organ in which freshly eaten leaves are stored. Horny ridges inside the crop, instead of pebbles, are contracted muscularly to help shred leaves, preparing them for bacterial fermentation. As in the sloth, particles being digested must be retained in the crop and foregut long enough for the bacteria there to ferment the leaf particles. Laboratory tests have shown gut retention times of over 40 hours, which is astonishingly long for a bird, but necessary to sustain a stable population of bacteria in the gut. Too much or too little leaf quantity could upset the amount of bacteria to the detriment of the bird.

The cost to the hoatzin of this abundantly available diet is thus relatively high. The modification of the crop into an efficient fermentation chamber results in its taking up so much space inside the bird that there is not enough room at the sternum (wishbone) for big flight muscles to attach. This explains the

hoatzin's poor flight ability; it takes two or more months for the chicks to fly. The chicks make up for their slow flight development by having wing claws that allow them to crawl nimbly around trees. When a predator threatens, they merely drop into the water under the riparian trees, sink to the bottom and slowly claw their way to the surface on tree roots. The extra weight of the crop at the base of the neck seems to throw the bird off balance, and it appears to hop awkwardly about the mangroves.

Thus in return for its ability to eat leaves, the hoatzin sacrifices flying agility in the adult and late flying development in the young. It can fly, however poorly, which means that it can exploit a habitat whose food source is often patchy. Clearly the continued presence of such odd looking birds indicates that their leafy diet is more advantageous to them than disadvantageous. A final added benefit is indirect but important. When skinned, the fermenting leaves in the hoatzin's foregut smell so strongly that the bird is known locally as the stinkbird. It is thus seldom hunted even though its flesh is perfectly palatable.

The green iguana (Iguana iguana) is a third arboreal folivore that exploits gut bacteria. This large lizard (2 m from nose to tail tip) spends about 90% of its time lying prone on a branch, digesting its diet of leaves. Like the sloth and the hoatzin, it is dependent on its gut bacteria for digestion, which in turn requires long food retention time and warm body temperature.

Iguanas, however, cannot chew as a sloth does nor have they a bird's crop. Therefore iguanas are the most dependent on gut bacteria for digestion. Their wide presence in the canopy of tropical New World forests is evidence of their success in exploiting the readily available and abundant variety of leaves that grow there. Problems can arise, especially for females, just before egg laying. Their body cavity is then so filled with eggs (from 40 to 60 for a big female) that there is not room enough for both food and eggs. Food takes second place, and gravid females can be severely stressed until they lay.

Life as a leaf-eater in the canopy is not easy despite what seems to be an inexhaustible food supply. Although leaves are indeed abundant, folivores must be selective and eat those leaves easiest to digest. These canopy dwellers must make endless decisions on which leaf to eat and where to go to find it, yet they must not move too fast or become too cold to upset the cooperating bacteria in their gut. Even a decision on how much sun to get on the tree top carries the risk of being targeted by large hawks and eagles. Clearly such decisions are not made rationally as humans might, but rather on experience and what used to be called instinct, but today is often labeled genetic

coding. Thus life for all beings is a trade off, and these three animals are a good example of how benefits have a compensating loss.

With this first letter of 1993, I wish you all a Happy New Year and urge you to visit Amazonia whenever you can. I will be happy to give you a tour.

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