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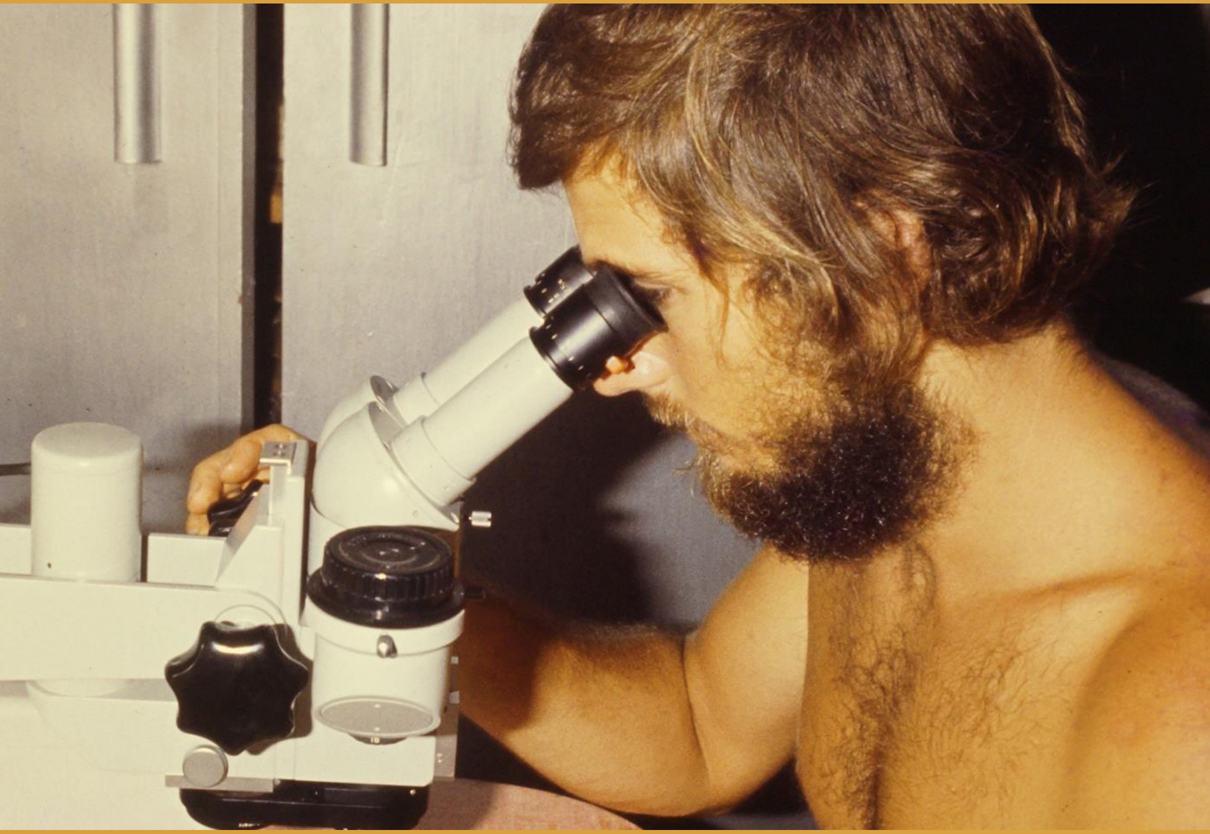
Tropical Lizards



To really understand how lizards control their temperatures, you have look inside them and follow their blood vessels. Photo of Bill in the early 1970s by Gordon Grigg.

During my Ph.D. research, I worked with Grahame Webb in Arnhem Land Aboriginal Reserve in the Northern Territory of Australia. Most of the time we weren't studying lizards and snakes, but Grahame had done his Ph.D. on temperature regulation in reptiles[71], and had published a paper on the morphology of reptile hearts[72]. He had equipment for studying thermoregulation in lizards, including thermocouples. These are constructed from very thin wires of different metals. The resistance across the point where they are soldered together depends on how hot they are, and measuring that resistance can give a very precise measure of temperature. Grahame said that we could study how tropical lizards used blood flow to regulate their temperature by warming the lizards under a heat lamp with thermocouples on or in different parts of their bodies. We would also be able to study the morphology of their circulatory systems by killing them and injecting different colored latex into their veins and arteries.

This was all very new to me. I enjoyed natural history, watching animals, and inventing just-so stories about why they behaved the way they did. However, controlling the situation, making careful measurements and actually testing your hypotheses was something that I had only encountered in second-hand reports of other people's research. The thought of being able to go deeper by experimentation intrigued me, but at the same time left me feeling somewhat inadequate because of my technology phobia.

The aboriginal people we worked with also had a different perspective on the natural history of lizards and snakes; the larger species were valued food items. Two of the people that I spent most of my time with were Dick Nuggarboi and his son Oscar Nalawade. I will use the aboriginal part of their names, rather than the epithets given them by the missionaries. Nuggarboi was accomplished with a spear, but had not fully mastered the new technology represented by shotguns. Nalawade was more familiar with the new technology, but had lost most of his fingers and toes to leprosy. When they were travelling with me in an outboard boat, they usually didn't take their long spears, which meant that they were dependent on shotguns to bring down game.

Photo 5.1 *Floodplain monitor:* Varanus panoptes. *Photo by David Kirshner.*

Often, when they had shot most of the bark off a tree surrounding a mangrove monitor[73] that was over a meter long and as round as my forearm, they would ask me to shoot it. I was a fair shot, but have to admit that I preferred to see the lovely darkly-speckled monitor lizards alive. After shooting the lizard, my first thought was to cut it open to see what it had eaten, but my aboriginal friends were adamant that that would make it unfit to cook. If I wanted the stomach, it would have to be pulled out through a small hole in the neck. The whole lizard was put into the ash from a fire and allowed to cook in its own juices.

Hunger is one of the best sauces for any food, but even so the dusty goanna did not look very appetizing when it was pulled from the fire. The skin had become hard and clunked when Nuggarboi hit it with a stick to remove the ash. A sharp knife split the center of the tail and the succulent white flesh contrasted with the dry skin. It was the best tasting wild food that I have eaten, before or after, and I understood why the aborigines so often hunted the large lizards.

Mangrove monitors lived in the forest along the rivers and spent most of their time in the trees, or gliding through the water with their heads held high on their long necks, propelled by graceful strokes of their flattened tails. Floodplain goannas[74], lived behind the mangroves on the floodplains. They were more drably colored than the water monitors, but grew much bigger, some being as thick as my calf. Their flesh was almost as good as that of the water monitors. Lizards are not only predators in their own right; they also support complex food chains that sometimes even include us.

The complexity of these chains is shown by the effects of the introduction of the cane toad, *Rhinella marina* (formerly *Bufo marinus*). Australian goannas had never been exposed to bufonid frogs before the cane toad was introduced in 1935, and so never evolved aversion to their deadly toxins. There is evidence that the Australian freshwater crocodile suffered because adults eat cane toads. However, the cane toads had a devastating effect on the floodplain goannas, which previously ate most of the crocodile eggs, and the crocodiles may have benefitted from the introduction of the toads[75]. Other species of lizards and snakes probably play keystone roles in regulating the densities of other organisms, but it generally takes a disaster for us to perceive this.

Photo 5.2 *A Richardson's mangrove snake eating a fish. Photo by Ruchira Somaweera.*

There are several species of goannas around Sydney, but these rarely enter mangrove forests, and there are no aquatic reptiles in the southern estuaries. Many species of snakes occur in the estuaries of northern Australia, and I would often sit in a boat at night with a light, watching as they foraged in the shallow water and the tide ran out exposing wide mudflats. Mudskipper fish and a variety of crabs crawled around on the exposed mud, but the snakes generally remained in the shallow water. The most common species were Richardson's mangrove snakes[76] and bockadams[77].

The mangrove snakes were a dull olive green with irregular black lines across the back. Their eyes were fairly high on the head and they were a little pudgier and less streamlined than similar-sized land snakes, but they did not appear to have any extreme adaptations for aquatic life. The bockadams had similar, but more reddish, coloration and appeared to be more adapted to an aquatic lifestyle;

their snouts were short and narrow compared to the thick neck and back of head. This, combined with prominent eyes placed high on the head, has earned them the name of dog-faced snake. Both species must have been among the major predators on the small fish of the shoreline.

I also collected a little file snake[78]. This species is related to the Arafura file snake I had kept as a pet, but generally occurs in brackish or salt water. Snakes are common in estuarine and fresh waters throughout the tropical World, but most are colubrids, a family of snakes that is relatively rare in Australia and restricted to northern areas. The three species of file snakes are in a family, Acrochordidae, all their own and, as far as I know, it is the only family of snakes that only has aquatic species. My ideas about snakes were beginning to change as I learned about the variety of species and habitats, but I remember relatively little of the individual snakes I caught during my studies in northern Australia, probably because I was very comfortable around them and they did not stimulate my subconscious enough to form long-term memories. However, others were probably more affected by my captive snakes. Below I reproduce a passage from an email sent to me by Chris Moran 40 years later.

> "Do you remember that bloody file snake you had in the caravan we shared in Maningrida? You put a small python in the tank with it and then accused me of letting the python go, not knowing that I wouldn't dare touch either of the snakes. A day or two later, as I walked out of the caravan, something rolled under my foot and it was the bloody file snake which had somehow clambered out of its tank, probably dying but certainly helped along that way by me walking on it. When you dissected it, your little python was inside the file snake!"

Photo 5.3 *The brown tree snake*, Boiga irregularis, *is common in northern Australia. This species exterminated many species of birds when it was inadvertently introduced to the island of Guam. Photo David Kirshner.*

I don't remember the incident, but from my notes I assume that it was a Richardson's mangrove snake and not a little python that was eaten by the file snake. I very likely also had a Children's python in one of the aquariums in the caravan we shared. Field biologists tend to be messy, and I am no exception. I never thought about how my slovenly habits might be stressful to Chris until one day when I saw him diligently cleaning the stove in the caravan that we never used and realized that laboratory biologists need to keep much higher standards than field ecologists. Chris ended up having a distinguished career as Professor of Animal Genetics in the Faculty of Veterinary Science at Sydney University.

I found quite a few snakes by searching the bush near the caravan, and even found a spectacular black snake with an orange band along each side that I thought was an undescribed species, but just turned out to be a secretive snake[79], also known as the northern small eyed snake. It is a close relative of the small eyed snakes I kept as a child, even though it does not have particularly small eyes. A friend also brought me a northern death adder that she had chopped in half when she found it on her front step. It was good to see the snakes in hand close up, but I couldn't outrun the black whip snakes[80] that lived around the base. They were well over a meter long and lived up to their name by being very agile. The easiest way to catch many species was to inspect small trees from a boat when the monsoon rains flooded the Liverpool River. It was not only the aquatic snakes that needed to know how to swim. The snakes of the floodplain had to swim and climb trees when the river overflowed its banks.

On my first trip up river during a flood, the seven-meter aluminum boat swayed in the flood eddies and the 50 hp engine sometimes made little headway where the water funneled through narrow canals between the mangroves, only the tops of which were above water level. I found many whip snakes in the trees, which were easy to catch as they had nowhere to go, and I also caught several species that would later become famous because of the many papers written about them.

I saw a rat swimming agilely from the strip of mangroves on one side of the river to the other, and we would have caught it if the eddies had not put us off course. I recognized it as a dusky rat[81], a species that generally moves from the floodplain to higher areas when the lower areas are flooded. I also found many water pythons[82] curled in the forks of the exposed trees. Thomas Madsen and

Rick Shine would make the ecological relationships between dusky rats and water pythons one of the best known examples of the abundance of prey determining the growth and reproduction of a predator[83]. However, even though I saw both species on the same day, I never imagined how much the water pythons depended on the rats.

Photo 5.4 *The dusky rat,* Rattus colleti, *is a critical food source for water pythons on the floodplains of northern Australian rivers. Photo by Ruchira Somaweera.*

The other species of which I caught many individuals when the floodwaters were high was the brown tree snake[84], a rear-fanged colubrid that occurs throughout much of Southeast Asia and Northern Australia. They are easy to catch but do not like humans, biting repeatedly if you are silly enough to get too close. We caught them with Pilstrom tongs, which are basically pincers on the end of a long shaft, like those used by cleaners to pick up rubbish in public parks, and we pushed the snakes into cloth bags before they could use their sharp teeth on us.

No snakes occurred on the Pacific Island of Guam, so the native birds did not evolve the defense strategies that allow birds to coexist with snakes in most of the World. When brown tree snakes got to Guam, possibly as stowaways on boats transporting bananas, they achieved much higher densities than they attain anywhere else, and drove most of the native birds to extinction[85]. Enormous efforts to control the snakes have been unsuccessful.

Undoubtedly, the most unusual lizard in Australia is the frillneck[86]. It has folds of skin on either side of its neck that it can extend to make a disk many times larger than the width of its body, or fold back along its back so that it appears to be enclosed by a cape. It was obviously the model for the dinosaur that killed the villain in the first Jurassic Park movie. Combined with red coloration and a gaping mouth, opening the frill constitutes one of the most spectacular displays in the animal kingdom.

Many species of lizards have folds of skin that they can unfold to show bright colors during aggressive interactions between males or to impress females. However, these are usually limited to small flaps on the throat that are rarely much larger than the animals head. When folded, the flaps of a Frillneck cover most of its body, and the lizards use the open frill to deter predators, including humans. I was impressed, and photographed the lizards, but I did not think about the other consequences of the huge frill until Grahame Webb asked “But what is the importance of that frill for heat regulation?”

Photo 5.5 *A water python in defensive position. The population dynamics of the species are closely tied to fluctuations in densities of dusky rats. Photo by Ruchira Somaweera.*

Humans control blood flow to different parts of their body to help control their temperatures. When we are cold, we restrict blood flow to our extremities, which can result in frostbite and the loss of fingers and toes due to lack of oxygen when we are in very cold places. When it is hot, we direct blood to the skin, making us flushed and sometimes swelling our fingers and feet. However, these responses usually only have a small effect on our temperatures, and rather than gaining or losing heat that is available for free in our environment, we mostly use energetically-expensive heat generation based on burning the large amounts of food we eat.

Lizards are much better at gaining and losing heat to their surroundings and they do not do this passively. By controlling blood flow from the center of the body to the skin, they are able to heat quickly when external sources are available, and to retain that heat much longer than would be possible if they were just passive heat conductors. In fact, simple conduction from warm or cold surfaces is often only a minor component of lizard thermoregulation. They are able to use radiant energy from the sun, which generally comes as light rather than heat, convert the light to heat energy at the skin surface and then transport the heat deep into the body using veins and arteries.

One of the earliest and most impressive detailed descriptions of lizard thermoregulation was made by Oliver Pearson for the small Andean lizard, *Liolaemus multiformis*[87]. He showed that the lizards left their burrows shortly after 7 a.m. when the air and soil temperatures were below zero and they attained temperatures 20 ℃ above those of air within an hour of starting to bask. At times, their temperatures were 30 degrees above air temperature, which never got much above 12 ℃, even in the hottest part of the day. Whereas air temperature is critical for us, and the reason we are always trying to predict it from the weather report, air temperature is almost irrelevant for many lizards, as long as they have access to sunshine.

Being able to use solar energy is not the only trick that lizards can use to conserve energy. We are dependent on our constant high temperatures, and if our core temperature drops even a few degrees below normal we will enter a coma and die. Although some lizards depend on high temperatures to reach maximum performance, all species can survive temperatures tens of degrees lower than their activity temperatures. They simply slow down their metabolism, a process analogous, but less costly in terms of energy, to our sleep. In this way, they can wait until conditions are again adequate for activity. In fact, if activity is limited by something else, such as lack of water or food, the lizards can seek a cool spot to slow down metabolism and conserve energy. We, in contrast, have no choice but to find food to burn or we begin to waste away and ultimately die.

Photo 5.6 *The collar of the frill-neck lizard is not only used to intimidate predators; it is probably important for maintaining the lizard at its desired temperature. Photo by David Kirshner.*

Although I had heard about lizard thermoregulation, it was completely different seeing it happen. We heated a frillneck lizard with heat lamps, sometimes with the frill covering its body and sometimes without. The thermocouples registered the differences in blood flow as the lizard first heated, then directed blood to avoid overheating. However, it was when Grahame Webb injected a dead lizard with colored latex and digested away the tissue to show the vascular system that I really started to understand the complexity of the system. By injecting into different parts of the heart, he was able make the arteries, which normally carry oxygenated blood, red, and the veins, which carry deoxygenated blood from the muscles to the lungs, blue.

The thin, apparently dry, skin of the frill was interlaced with a complex network of veins and arteries. Rather than a simple cloak, it was obvious that it was a sophisticated heat-transport system. Injecting latex was a simple technique, but just seeing the lacework of blue and red latex made me realize how inadequate my mental image of lizards as balls of muscle at the mercy of air and ground temperatures had been. We are only just starting to realize how important it is to use renewable sources of energy, such as solar panels and wind turbines, rather than inefficient internal-combustion engines, to generate electricity. The lizards had it worked out long ago!

Other things came up and we never finished the thermoregulation experiments, nor did we publish the results. However, my mental model of the World had changed, and that would affect the ecological studies I would do on another continent, decades later.