Gliding Lizards in the Genus *Draco* use wings for "flight" and also to facilitate species recognition and intra-species communication.

The Flying Reptiles of Peninsular Malaysia

L. Lee Grismer

Department of Biology, La Sierra University, Riverside, California, 92515, U.S.A.

Photographs by the author except when otherwise indicated.

Standing on the peak of Gunung Kajang on Tioman Island after a miserable, leech-infested, three-day climb to the summit, I was looking across a deep valley toward the twin peaks of Nenek-Semukut wishing I could spread my wings, glide between the peaks across the valley, land on the beach at Mukut, and crack open a nice, cold drink — anything to keep from hiking back down that mountain. As it turns out, I'm not alone. Flying has been a preoccupation of humans for time on end. Sadly, however, humans will never acquire the capability of unassisted flight and we'll have to continue appeasing and teasing ourselves with everything from hang-gliders to space shuttles.

In other vertebrates, however, flying is really no big deal. Some fish leap out of the water to escape predators, extend their enlarged pectoral fins, and glide for hundreds of meters. Many frogs have extensively webbed, elongate fingers and toes that function as parachutes when they leap from the leaves and branches of trees to glide across the forest. Several groups of mammals, ranging from bats to rodents to colugos, have evolved many different ways to move through the air. Reptiles have been flying for millions of years. The earliest fliers were the Frigate Bird-like pterosaurs. They were also the first reptiles capable of powered flight and ranged in size from chickens to giants having wingspans of over 16 m. However, the most successful flying reptiles of all time are (not were) the dinosaurs and their modern-day representatives — birds.

In southeastern Asia, modern, non-avian reptiles have gone crazy and flight of some sort has evolved independently at least three, maybe four times in lizards, and once in snakes — but why flight, and why in southeastern Asia? Although a number of hypotheses have been proposed, the overarching theme

The Bronzeback Snake (*Dendrelaphis cyanochlorus*) is an adept climber that frequently preys on arboreal lizards.

Black-bearded Gliding Lizards (*Draco melanopogon*) have light bodies with big wings and can attain lift immediately after leaving the tree, even at slow speeds, and are capable of considerable in-flight maneuverability.

Spotted Forest Skinks (*Lipinia vittigera*) often forage on trunks of trees, but lack the escape capabilities of gliding lizards.

throughout all of them is predator evasion. Think about it: You're less than 15 cm in body length, you have no formidable defenses, and you're living in a jungle. By default, that makes you one of nature's "fast-food" entrées. So, if you want to avoid becoming the next McLizard in the Rainforest Happy Meal, you had better develop an effective escape mechanism.

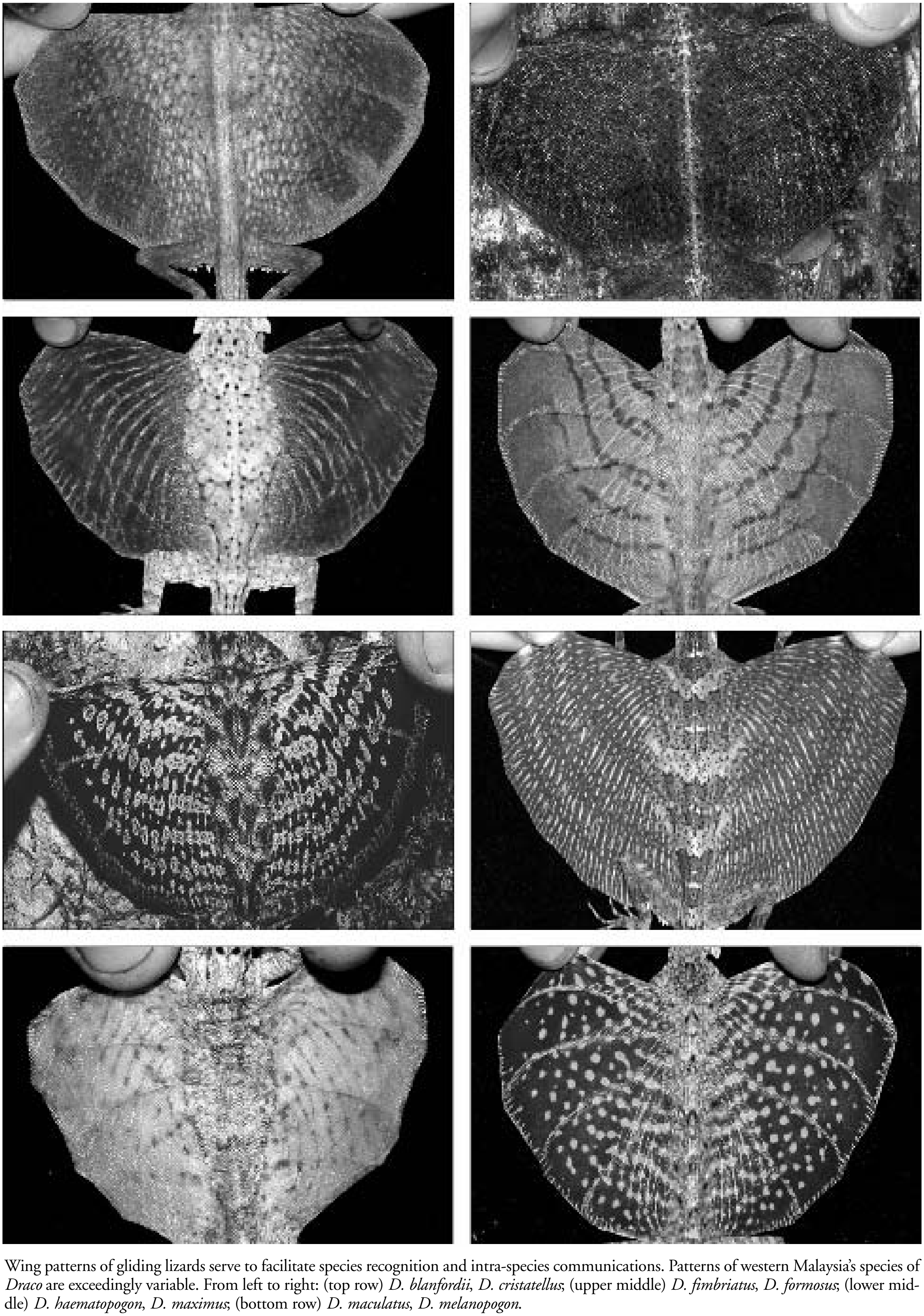
This always seemed logical to me, but it really hit home one afternoon while I was taking a break along the banks of the Sungai Mentawak on Tioman Island. I was just about to resume my hike when I noticed a Bronzeback Snake (*Dendrelaphis cyanochloris*) crawling up the trunk of a large tree. This snake's ability to climb on flat, vertical surfaces had always fascinated me, so I decided to watch for a while. Its coils were purposely looped in just the precise way necessary for gaining purchase on the irregularities of the tree's surface as it continued to effortlessly push itself upwards. Then I noticed it was ever so slightly moving its head from side to side and rapidly flicking its tongue — the telltale signs that it was following a scent-trail. At that very moment, I saw a Black-bearded Gliding Lizard (*Draco melanopogon*) leap from the tree and glide through the green, filtered light of the forest to land on a different tree. Then, suddenly, the snake struck and grabbed a Spotted Forest Skink (*Lipinia vittigera*), which I hadn't seen, right off the side of the tree. While the Bronzeback Snake gnawed and manipulated the Forest Skink in its mouth, to position it just so before swallowing, I realized that this particular little skink and I had something in common; we both wished that we could fly.

What made that crucial life-or-death difference between the skink and the gliding lizard was a wing. In fact, gliding lizards (genus *Draco*) are southeastern Asia's most adept flying reptiles, and their wings have clearly contributed to their widespread distribution (India to eastern Indonesia) and radiation (over 40 species). Oddly enough, the *Draco* wing is just a marvelously rearranged rib cage. The opposing ribs, the ends of which normally meet in the center of the body to form a bony basket (i.e., the rib cage) to protect the heart and lungs, have become disconnected. The ribs have lengthened and now lie bunched up alongside the body when not flexed. Muscles in the chest that normally lift and elevate the rib cage to draw air into the lungs now pull the ribs forward and outward, opening the wing. The amount of skin along the sides of the body has increased and now functions as the flying surface that the lengthened ribs support. Although this wing is not capable of generating power, it does provide enough lift to extend the length of the glide and provide considerable in-flight maneuverability.

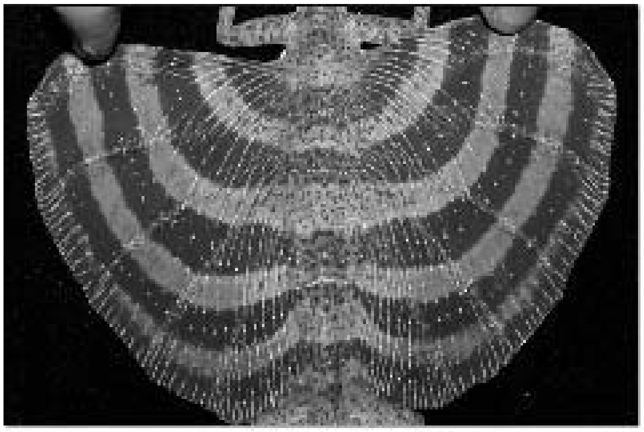
Gliding lizards use their wings for more than just flight, however. These expansive surfaces also function as prime advertising space for communicating to other gliding lizards. Each of Malaysia's 11 species has its own, unique wing pattern.

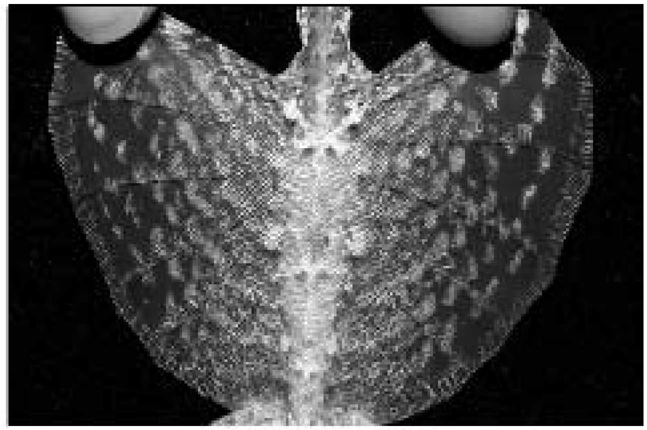
When not flying or displaying, gliding lizards are commonly seen sitting head-up on the trunks of trees with their wings inconspicuously folded against their bodies. They spend many of their daylight hours running up and down trees feeding on ants, which make up the vast majority of their diet. However, when it's time for a change of scenery, they simply leap from the tree, extend their ribs to open the wings, and glide to the next tree. The extent and speed of the glide depends on a couple of factors: Height of the lizard on the tree and the surface area of the wing relative to the weight of the body. As it turns out, not all *Draco* are created equal. The smaller, frail Black-bearded Gliding Lizard, with its pencil-neck and light bulb-shaped head, has a light body with big wings, attains lift immediately after leaving the tree, even at slow speeds, and is capable of considerable in-flight maneuverability. In stark contrast, the Orange-bearded Gliding Lizard (*D. fimbriatus*), with

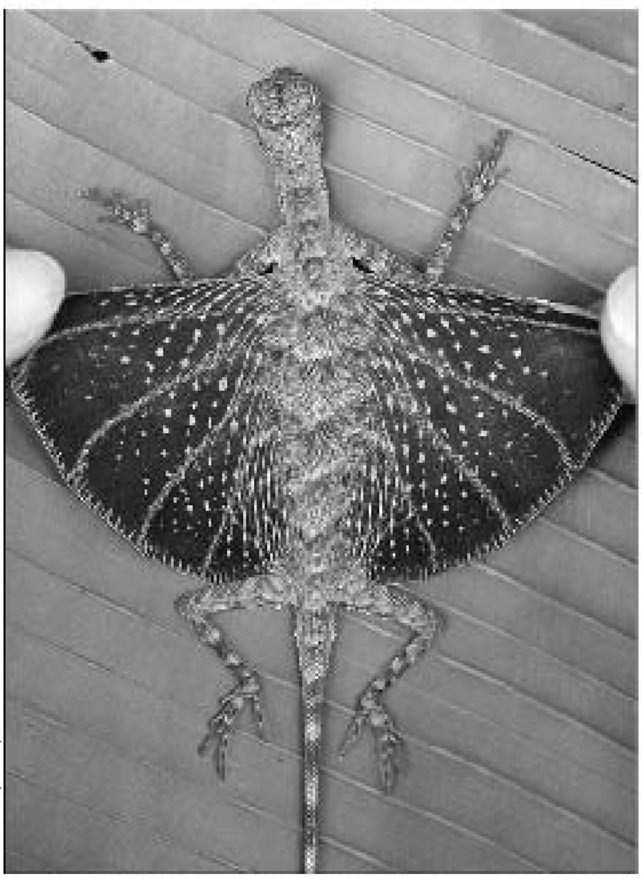
Orange-bearded Gliding Lizards (*Draco fimbriatus*) have thick necks, heavy, robust bodies, and relatively small wings; consequently, in-flight maneuverability is poor, but glide speed is very fast.



Wing patterns of gliding lizards serve to facilitate species recognition and intra-species communications. Patterns of western Malaysia's species of *Draco* are exceedingly variable. From left to right: (top row) *D. blanfordii*, *D. cristatellus*; (upper middle) *D. fimbriatus*, *D. formosus*; (lower middle) *D. haematopogon*, *D. maximus*; (bottom row) *D. maculatus*, *D. melanopogon*.







FRANS LANTING (BOTTOM)

More wing patterns of western Malaysian species of *Draco*: *D. quinquefasciatus* (top left), *D. sumatranus* (top right), *D. taeniopterus* (middle), and *D. melanopogon* (bottom; note the variation in the extent of stippling when compared to the individual illustrated in the previous figure).

its thick neck and heavy, robust body and relatively small wings, has poor in-flight maneuverability but a very fast glide speed. In fact, when this species jumps off a tree, it has to dive straight down with its wings folded against its body until it picks up enough speed to open them up and glide. When it does glide, it looks like a jet rocketing through the forest. Consequently, Orange-bearded Gliding Lizards often are found high in some of the forest's tallest trees, from which they can safely dive in order to gain the momentum necessary to initiate the glide. Black-bearded Gliding lizards usually are found on lower portions of trees.

As it turns out, this is one of the reasons these two species can coexist in the same forest and even on the same trees. Their flight anatomy helps separate them ecologically and keeps them from competing directly for some of the rainforest's resources. In certain areas of the forest, up to eight different species of *Draco* may occur together. Generally, when closely related species with unique, restrictive life histories (and being an arboreal, flying, anteater is pretty restrictive) live in the same area, the potential for competition is high and resources must be carefully partitioned. *Draco* do this in such a way that you rarely see more than two species in close proximity. For example, Common Gliding Lizards (*D. sumatranus*) and Spotted Gliding Lizards (*D. maculatus*) are common in open and disturbed areas; Five-banded Gliding Lizards (*D. quinquefasciatus*) are usually found in dense forest with relatively small, closely-spaced trees; Giant Gliding Lizards (*D. maximus*) are somewhat restricted to riparian areas; smaller Yellow-bearded Gliding Lizards (*D. haematopogon*) and larger Blanford's Gliding Lizards (*D. blanfordi*) occur at higher elevations than most other species; and Black-bearded Gliding Lizards and the larger Dusky Gliding Lizards (*D. formosus*) are habitat generalists in lowland forests.

However, Gliding Lizards aren't the only flying, reptilian denizens of Malaysia's rainforests. As if geckos weren't weird enough already, with their big heads, bulging lidless eyes, ability to vocalize, and elaborate hands and feet, some can add flight to their résumés. As exemplified by Flying Geckos (genus *Ptychozoon*), their wings lack the elaborate thoracic (chest) modifications of Gliding Lizards. Instead, they are composed solely of a large flap of skin along their flanks. These flaps remain folded across the belly until the lizard jumps from a tree. At that point, they become passively opened by air during the descent. Accompanying the body flaps are extended flaps along the sides of the head, neck, and tail, backsides of the hind limbs, and extensive webbing on the hands and feet. During flight, when all the flaps and webbing are splayed and extended, they serve to provide more of a parachuting effect rather than generating lift as with the wing of a Gilding Lizard. Nonetheless, I have seen Kuhl's Flying Gecko (*P. kuhli*) display remarkable in-flight maneuverability and actually change directions 180° during flight.

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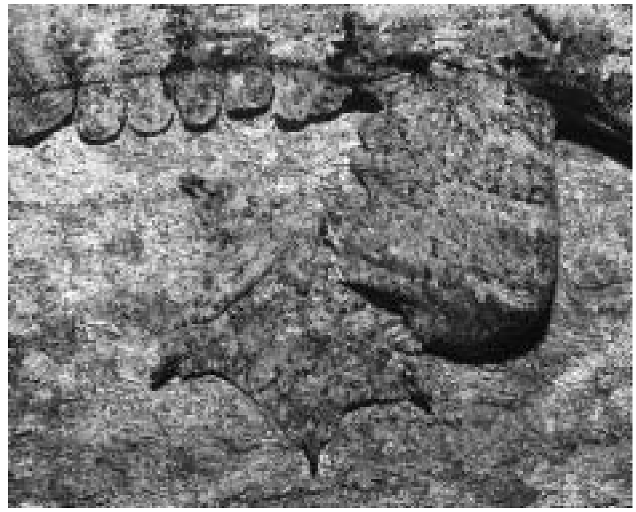
Nesting female *Draco sumatranus*.



Tail and thigh flaps and webbed foot of a Flying Gecko (*Ptychozoon kuhli*).

Very similar flying surfaces have evolved independently in an unrelated species known as the Frilly Gecko (*Cosymbotus craspedotus*). The Frilly Gecko is smaller than most Flying Geckos and has not been observed demonstrating the same in-flight maneuverability or ability to glide from tree to tree. It usually uses its parachuting capabilities to glide from one portion of a tree to a lower section of the same tree in order to avoid predators.

The different means by which these distantly related groups of lizards have solved the same problem (making a wing to escape predators) beg an interesting evolutionary question. I mean, if you're a lizard and you're going to make a wing, why not do it the same way? Well, it probably has a lot to do with the general life styles of the members of their respective families to whom they are related. In southeastern Asia, the Agamidae, the family to which Gliding Lizards belong, are arboreal, diurnal, conspicuous insectivores that signal to one another by puffing out their throats and expanding their chests to display their brilliant color patterns. They also jump from branch to branch in search of prey and to escape predation. So, in a sense, they can already do everything necessary to fly — jump from one place to another and expand their rib cages. Now all that's necessary is to do them both at the same time and let natural selection run its course. In support of this hypothesis is a remarkably obvious intermediate condition in the Green Crested Lizard (*Bronchocela cristatella*), a common, arboreal agamid also native to southeastern Asia. When threatened, Green Crested Lizards will leap from one tree to next, splay out their limbs, and expand their rib cages during flight. Although they have no trace of a wing, the increased surface area resulting from the expanded rib cage and splayed limbs significantly decreases the angle of the drop and extends the length of the "glide." So, seeing how natural selection may again, within the same selection regime and same related group of lizards, be developing flight in the Green Crested Lizard is not hard to imagine.

Geckos (family Gekkonidae), however, are cryptic species that attempt to go undetected during the day and are active at night. All the displaying and leaping common to many agamids

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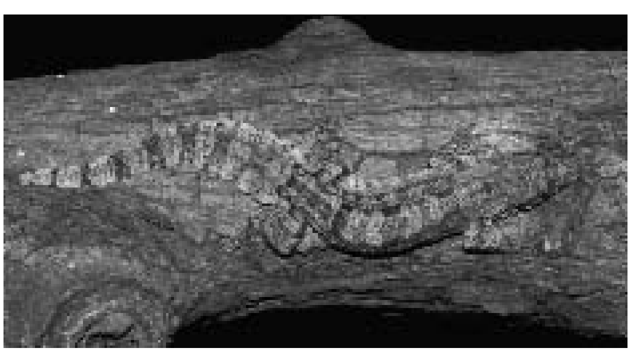


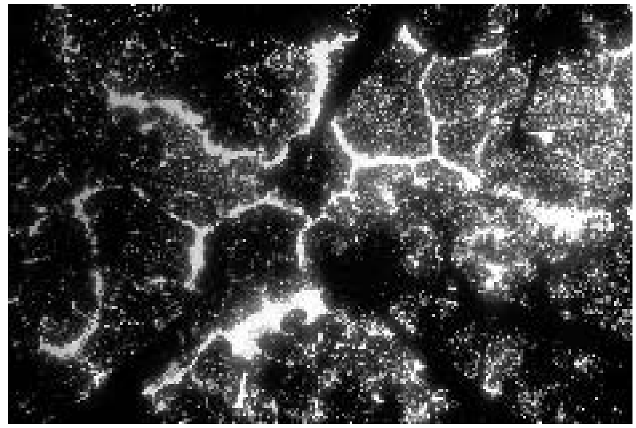
Frilly Geckos (*Cosymbotus craspedotus*) usually use their parachuting capabilities to glide from one portion of a tree to a lower section of the same tree in order to avoid predators.

do not happen in geckos. In fact, their color patterns generally match the substrate on which they reside, enabling them to go unnoticed. Interestingly, the Flat-tailed Gecko (*Cosymbotus platyurus*), a species closely related to the Frilly Gecko, presents us with another example of intermediacy. It has the same folds of skin along the head, body, limbs, and tail as the Frilly Gecko, but they're not nearly as well developed. These geckos lay these flaps out on the trunk of the tree to prevent the curvature of the body from casting a shadow where it contacts the trunk in order not to give away its location. If these flaps passively opened up like they do in other geckos when this gecko jumps from one branch to another, and this imparted even a small advantage by extending the length of the jump, natural selection will come into play. This is a likely example of what evolutionary biologists refer to as "preadaption" — a situation in which a structure evolves to be used in one context (camouflage) and becomes modified later to be used in a completely different context (flight).

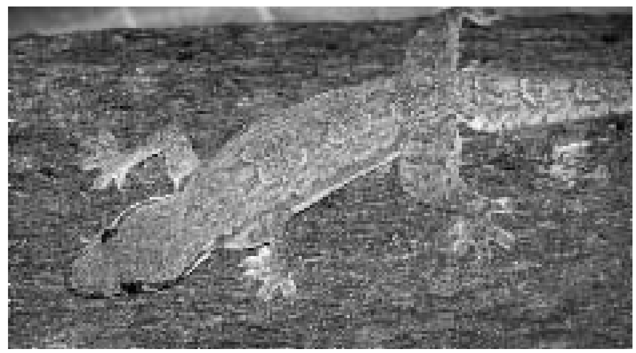
Because of their lack of limbs and other appendages, one might think that the most unlikely group of vertebrates to evolve flight mechanisms would be snakes. However, in peninsular Malaysia, three, closely related species of snakes have the ability to glide for considerable distances. These are the Tree Snakes (genus *Chrysopelea*). Their flight modification involves a simple little notch on each side of each belly (ventral) scale where the ends turn upwards along the lower sides of the body. This notch works like an expansion joint, allowing Tree Snakes to flatten out and widen their bodies. The flat, wide body works like a parasail, and its undulatory movements during flight, analogous to a spinning frisbee, stabilize the body to prevent it from overturning. Prior to launching themselves from branches, Tree Snakes hang the uncoiled forepart of their body off the branch in a "J-loop." Then, by rocking the body upward while simultaneously springing outward by rapidly straightening their coils and releasing their hold on the branch, the snakes take flight. Intermediate conditions to this style of flight are found in related, semi-arboreal snakes such as Bronzebacks (mentioned earlier), which have notched ventral scales that help anchor them to the substrate while climbing vertical surfaces. They also expand their rib cages as a defense mechanism to expose brightly colored markings on their scales. So, the three main ingredients, arboreality, notched ventral scales, and a behavior involving the expansion of the rib cage, already existed in this group of related snakes — perhaps another example of preadaptation.

So, back to the earlier questions of "why flight, and why here in southeastern Asia?" I think I've pretty much answered "why flight," so let's look at "why in southeastern Asia?" With the exception of birds and bats, when you compare the number of flying vertebrates in Asian and Australasian rainforests to those in the world's other major rainforest ecosystems — Central and South America and Africa — a striking pattern emerges. These other rainforests have no flying vertebrates. Also, no really solid or generally agreed upon hypotheses explain why. However, the most common explanation suggests that the presence of flying reptiles has to do with Asian rainforests lacking the extensive vines and understory vegetation that, in the other rainforests, connect adjacent trees to one another. Additionally, the crowns of some trees in Asian rainforests are discontinuous. In fact, in species such as the Kapur (*Dryobanalops aromatica*), the crowns of adjacent trees chemically repel one another. Consequently, getting from one tree to the next is more difficult for arboreal species unless they climb down to the ground and walk across the forest floor, running a substantial risk of becoming prey for some opportunistic predator — so they fly.

Whatever the reasons behind these remarkable evolutionary success stories, I don't think I will ever become accustomed to standing in the forest and seeing a snake go gliding by overhead or a Giant Gliding Lizard with a wingspan like that of a small pigeon leap from a tree to glide 30–40 meters across a stream and land on another. In no other rainforests in the world can we enjoy these natural eccentricities, which leaves me saying to myself once again, "I sure wish I could fly."



Crowns of adjacent Kapur Trees (*Dryobanalops aromatica*) chemically repel one another, resulting in a discontinuous crown.



Flat-tailed Geckos (*Cosymbotus platyurus*), a species closely related to the Frilly Gecko, use folds of skin along the head, body, limbs, and tail to prevent the curvature of the body from casting a shadow on a tree trunk and giving away its location to a predator.

Tree Snakes (*Chrysopelea*) flatten out and widen their bodies and can glide for considerable distances. From top to bottom: *C. ornata*, *C. paradisi*, and *C. pelias*.