Being one of the most biologically diverse ecosystems on Planet Earth, the tropical rainforest used to cover most of Singapore. Unfortunately, much of Singapore's original jungle has been lost to human civilisation. Although small in size, these remnant pockets harbour rich plant and animal life, which, despite two centuries of study, still hold secrets and surprises that are still being revealed to this very day. Following the style and philosophy of the three earlier books in this 'Private Lives' series, we have put together a collection of short stories and anecdotes about the life and times of the various organisms in Singapore's tropical rainforest. These are accounts of how they have adapted to the environment, about how they interact with each other, and rely on one another to survive. We hope that the reader will be entertained by these fascinating tales of the cast of real-life characters, and become aware of the plight faced by them, and the efforts made to protect the tropical rainforest.

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PRIVATE LIVES An Exposé of Singapore's Rainforests

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PROLOGUE

Wang Luan Keng, Darren C.J. Yeo, Kelvin K.P. Lim and Shawn K.Y. Lum

It may surprise some to learn that 'green areas' in Singapore consist of more than just parks, gardens, and golf courses. Some of the greenery in Singapore is actually of the forest variety—tropical rainforest, to be precise. Singapore is in fact one of the few cities in the world that can boast of having primary tropical rainforest and even freshwater swamp forest, in the midst of a very urbanised landscape. Here, one could be in the bustling metropolitan area at one moment, and in a matter of minutes, be among the serene majesty of some of the most ancient rainforests on earth.

This book therefore is all about Singapore's tropical rainforests. It describes the essence of our forests through anecdotes about the unique combination of features and denizens that set them apart from other habitats. It is, in effect, a peek into the private lives of Singapore's forests. Reflecting the broad, multifaceted importance of our forests, this book is a group effort, bringing together the expertise and experience of diverse individuals including biologists, amateur (but expert) naturalists, educators, managers, and conservationists, among others.

With so many ways to present the stories of the rainforest, we had to ask ourselves: *Where do we start? What do we cover?* In the end we decided that the coverage of the book should focus on three areas: organisms and aspects that are easily seen if one were to take a walk in forest; what comes to mind when we think about or talk to people about forests; and what anecdotes many of us, who have experience with the forest, tend to relate when we bring groups of people for guided walks in the forest.

The book has three main parts. The first part forms the backdrop to the rest of the book by introducing Singapore's rainforests, including its physical and biological make-up. The second—and main part of the book—provides snapshots of various organisms or groups of organisms as they go about the business of living in the rainforest. This covers form and function, autecology, and interactions between organisms and the environment. The final part looks at man and the rainforest. While this is not necessarily a natural association, it is nevertheless one that cannot be ignored. Human-forest associations include our exploitation of forests for the many familiar goods or products; forest features that are potentially hazardous to humans; and our roles as stewards of this invaluable resource. Some rather obvious components of rainforests have not been covered, for instance, forest streams, or dragonflies, as many of these are already covered in other books in the *Private Lives* series as well as in local scientific literature.

This book is the fourth instalment in the *Private Lives* series, which has been published since 2007 by the Raffles Museum of Biodiversity Research, National University of Singapore, with sponsorship from ExxonMobil. The series has evolved somewhat—the earlier volumes

were designed more as pictorial guides, whereas this latest volume includes more detailed accounts in addition to copious photographs—but the underlying motivation remains the same. The present book on our rainforests, together with the three previous titles, *An Exposé of Singapore's Shores* (2007), *An Exposé of Singapore's Mangroves* (2008), and *An Exposé of Singapore's Freshwaters* (2010), cover a range of habitats, which while unfamiliar to many, are still in existence here—and within reach. We hope that Singaporeans and visitors alike are inspired by the stories in this book (and the other three volumes) to learn more about and experience more of our precious natural heritage.

The emergent layer consists of the tops or crowns of the tallest trees in the forest that literally 'stand out from the crowd', rising far above the majority of the other trees. Because there are not as many of these individual trees as those of the other species, emergents form a broken or discontinuous layer. Emergents in Singapore's forests may be over 40 m tall and are mostly members of the dipterocarp family such as **Seraya (*Shorea curtisii*)**, **Meranti Tembaga (*Shorea leprosula*)**, and **Keruing Gasing (*Dipterocarpus caudatus* subsp. *penangianus*)**, as well as some members of the bean family (Fabaceae), including **Kempas (*Koompassia* spp.)**, **Keranji (*Dialium* spp.)** and **Sepetir Daun Tebal (*Sindora wallichii*)** and some members of the mango family (Anacardiaceae), including **Rengas (*Gluta wallichii*)** and **Red Dhup (*Parishia insignis*)**.

The **Red Dhup (*Parishia insignis*)**, an emergent that can be seen at the Bukit Timah Nature Reserve.

The crowns of tall forest trees (arrowed) can be seen above the main canopy top layer.

BIOTIC FEATURES

In addition to the abiotic characteristics mentioned in the previous chapter, tropical rainforests can also often be characterised by their biotic or living components. This chapter talks about some of these unique biotic features that include physical attributes or natural phenomena, mostly to do with the trees or other plants that dominate tropical rainforests. Some of the features conjure up popular images associated with tropical rainforests, e.g., of an impenetrable jungle of giant trees with plants of all shapes, sizes, and colour; while others might perhaps be less well known, e.g., the rarity of flowering in such a plant-dominated habitat, punctuated by periodic gluts of flowering exuberance.

Seraya (*Shorea curtisii*)

Kapur (*Dryobalanops aromatica*)

Mersawa Merah (*Anisoptera megistocarpa*)

Resak Buah Cana (*Vatica ridleyana*)

Damar Hitam Gajah (*Shorea gibbosa*)

The fruit of the dipterocarp has a single seed and has anything from two, three, to even five membranous, wing-like sepals, resembling a badminton shuttlecock (although some species lack these sepals altogether). The 'wings' do not really help the seeds to be dispersed well. Instead, most dipterocarp seeds fall below the parent trees, where they germinate immediately on the moist forest floor. Those seeds with longer wings might rotate as they fall, causing them to possibly drop a few metres further away from the parent tree.

The **Sandpaper Vine (*Tetracera indica*)** climbs by twining around supporting trees and shrubs. More often seen at forest edges, it not only just climbs upwards, but also grows new shoots sideways through the vegetation as well, forming almost a hedge at times—giving the appearance of a dense curtain along the forest edge. Out in the sun, it produces beautiful whitish flowers with numerous pink stamens which develop into fruits containing several black seeds enveloped in bright red filaments. **LHK**

The **Sandpaper Vine (*Tetracera indica*)** is so named because of the tiny unidirectional hairs covering the underside of leaves and young shoots. The stiff hairs help prevent the climber from slipping from its support. You can feel the rough texture by running a finger across the leaves and reddish shoots.

Habit of the **Sandpiper Vine (*Tetracera indica*)**.

(From left) Flowers, fruits and seeds of ***Tetracera indica***.

WHO SPAT ON THE LEAVES?

A blob of spit seen on the herbaceous plants in the rainforest is not left behind by an inconsiderate person but is actually produced by the nymphs of small insects, called **Froghoppers (superfamily Cercopoidea)**. These are small and stout bugs with strong legs. The nymphs feed on plant sap by piercing the plant tissues with their long, piercing mouthparts. Excess fluids are secreted by the nymphs as tiny bubbles, mixed with respiratory air emitted from the anterior spiracles, by moving or pumping their bodies. Once the bubbles are formed into a frothy mass, resembling spittle, the nymphs cover themselves with the froth. Hence these nymphs are commonly known as Spittle Bugs. The froth has an unpleasant taste and serves to deter predators. It also insulates the nymphs from extreme temperatures and prevents them from drying out. Size: 10–15 mm. **WLK**

The spittle produced by the nymphs of froghoppers is not spit at all but is liquid produced from the other end of the insect!

Froghoppers are so-called as they have the ability to jump very high, from plant to plant.

Dark Posy (*Drupadia theda thesmia*).
Size: wingspan 28–32 mm.

Harlequin (*Taxila haquinus haquinus*).
Size: wingspan 35–45 mm.

Malay Viscount (*Tanaecia pelea pelea*).
Size: wingspan 55–70 mm.

Blue Helen (*Papilio prexaspes prexaspes*).
Size: wingspan 80–95 mm.

Yamfly (*Loxura atymnus fuconius*).
Size: wingspan 28–32 mm.

Malay Lacewing (*Cethosia hypsea hypsina*).
Size: wingspan 60–80 mm.

FLYING SNAKES

While the *Draco* lizards are equipped with a pair of wing-like patagia, it is hard to imagine how a snake can be airborne without wings. Arboreal snakes of the genus *Chrysopelea* offer the answer. These snakes really can glide, but they accomplish this feat without special appendages. When a snake launches into the air, it flattens its body to resemble a ribbon, and sucks in its belly to trap a cushion of air beneath. This enables the snake to execute a controlled glide to a point of lower elevation, and even change direction in mid-air. Two species are known from Singapore: the **Paradise Gliding Snake (*Chrysopelea paradisi*)**, a common species that also inhabits urban parks and roadside trees, and the **Twin-barred Gliding Snake (*C. pelias*)** which seems to be confined to forest. These snakes appear to be largely diurnal in habit, and feed mainly on lizards and frogs, which are subdued with constrictions and venomous bites. Size: to around 1 m. KL

Twin-barred Gliding Snake (*Chrysopelea pelias*) is mildly venomous and can be found mainly in the Central Catchment Nature Reserve.

(Right): The **Paradise Gliding Snake (*Chrysopelea paradisi*)** is exclusively arboreal and feed on lizards and other small vertebrates.

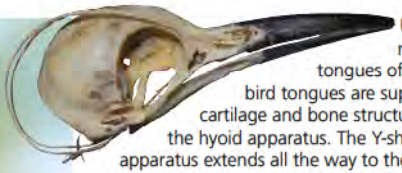
FOREST BUFFET

The rainforest provides bountiful nutrients to the animals. Arboreal and flying animals may exploit fruits, flowers and leaves in the forest canopy. Terrestrial animals must wait for these foods to fall from above (or to be dropped by arboreal frugivores such as monkeys, birds or fruit bats) or make the most of what is available growing close to the ground. Many animals also seek newly-sprouted leaves of forest herbs, tree seedlings and shrubs in forest gaps, in clearings and at forest edges—anywhere where a gap in the forest canopy lets enough light to stimulate shoot growth at ground level.

JACK HAMMER

Woodpeckers (family Picidae) are highly specialised birds with powerful, chisel-like bills that are capable of excavating holes in tree trunks. Woodpeckers are able to hop vertically up a tree trunk, with the help of stiffened tail feathers and zygodactyl feet (two toes pointing forward and two toes pointing backwards). Many are sexually dimorphic, with the males being more brightly coloured than the females. The diet of woodpeckers comprises largely of termites, beetle grubs, adult beetles, and other insects found in rotting wood. Woodpeckers pick off their prey items and can probe into holes with the aid of an extensible and very sticky tongue. They can also dig into bark and wood with their powerful bills, which gives them access to a source of food—wood-boring insects—that is not readily available to most other birds.

In our rainforests, the sharp piercing screams of the **Banded Woodpecker (*Chrysophlegma miniaceus*)** are often heard. Size: 25–27 cm.



Unlike the muscular tongues of humans, bird tongues are supported by a cartilage and bone structure known as the hyoid apparatus. The Y-shaped hyoid apparatus extends all the way to the tip of the tongue. The 'horns' of the hyoid grow backwards from the throat and provide the insertion sites for the lower jaw muscles. In woodpeckers, the 'horns' extend all the way up to the top of the head, grow around the eye socket and even extend into the nasal cavity! When the lower jaw muscles contract, the horns of the hyoid apparatus are pulled and the whole hyoid apparatus is pulled forward and against the skull, thrusting the tongue out of the mouth. This effectively extend the length of the tongue of the woodpecker, an adaptation for feeding on wood-boring insects.

Woodpeckers nest in tree holes, which they excavate themselves with their bills. During excavation, a woodpecker may hammer away at a dead trunk for several hours in a day, producing a far-carrying hollow sound or drumming. The drumming may also act as a territorial display. One might wonder how the woodpeckers survive such drumming without getting a brain concussion. Scientists have studied the action of the woodpecker's bill and discovered that when the tip of the bill hits the tree trunk, the protractor muscle pulls the hind jaws forwards, causing the upper mandible to tilt upwards, thus counteracting the downward force produced by the blow. Unlike other birds where the bones of

NOSEY PORKER

There may not be any more pig farms in Singapore, but pigs are certainly in our midst. We are talking not about the domestic pig, but its wild cousin. The **Eurasian Wild Pig (*Sus scrofa*)** has an interesting history in Singapore. The species was believed to have become extinct in Singapore possibly around the time of the Japanese Occupation, apparently from overhunting. There were no records again until the 1980s—pigs were sighted on Pulau Tekong when that island was reserved for military use. These animals must have colonised the island by swimming across the Johor Straits from Malaysia. Since the new millennium, Wild Pigs have become a common feature on Pulau Ubin and the Western Catchment Area, and they have since found their way into the CCNR, and even some suburban areas. However, not many people seem to be aware of this large animal. Wild Pigs tend to be extremely shy and wary, bolting at the mere sight or whiff of humans. Their presence in an area is often betrayed by their rooting activities. Pigs use their strong but sensitive snouts to turn over the earth to reach buried tubers, shoots, fallen fruits, seeds, worms, grubs, and other small animals on which they feed. As most of their natural predators (e.g. tigers and leopards) have become locally extinct, and humans are prevented from hunting them for food, their numbers seem to be increasing at potentially worrying rate. They breed all year round, and each sow can produce up to eight stripey piglets per brood, as frequently as eight months apart. Excessive pig rooting can adversely affect the survival of tree saplings in the forest, and pigs that have lost all fear of humans may become a dangerous nuisance. Size: head and body length up to 1.5 m. **KL**

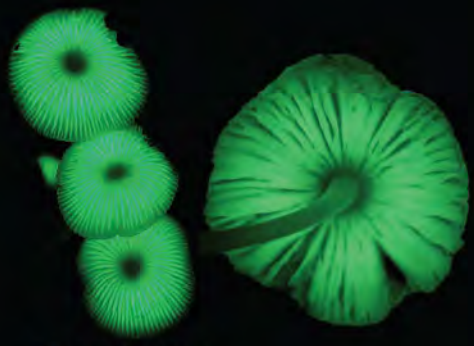
The **Eurasian Wild Pig (*Sus scrofa*)** is distinguished from its domesticated cousins by having a mane, and long coarse hairs covering its body.

CICADA CHORUS

The shrill and monotonous songs of cicadas are one of the signature sounds of the rainforest. **Cicadas (family Cicadidae)** are stout-bodied insects with long, membranous wings. They produce continuous high-pitched sounds by vibrating a pair of cuticle plates on the sides of their abdomen. Each species produces its own unique song, and only the males sing. The songs, performed during the day, are for attracting mates as well as challenging other males for the opportunity to mate and pass on their genes. Gravid cicadas lay eggs in slits cut into tree bark with their sword-like ovipositor. When the nymphs hatch, they drop to the ground, and burrow into the soil with their claw-like front legs. They may live underground for many years, feeding on the sap of tree roots. When ready to metamorphose into adults, the nymphs emerge from the soil and crawl up a tree. They then break out of their exoskeleton, and take a while to unfurl and dry their wings before flying off to find mates to produce another generation of cicadas. The adults obtain nourishment by sucking sap from trees. They usually live no longer than six weeks. The large green cicadas that inhabit our forest are from the genus *Dundubia*. Size: up to 100 mm. **KL**

Cicadas (*Dundubia* spp.) are well camouflaged on tree trunks and are hard to spot.

The nymph of the cicada is equipped with a pair of digging legs. The empty exoskeletons (exuvia) of cicadas can often be found on the trunks of trees.



Mycena illuminans

GLOWING MUSHROOMS

As night falls, clusters of a dim light can sometimes be seen in the forest undergrowth. These are produced by bioluminescent mushrooms. Fallen leaves are usually covered with the hyphal threads of the fungus, so that on a pitch dark night, the forest floor seems to be glowing eerily. Scientists have suggested that the fungus is luminescent to attract nocturnal flying insects to the fungus, so aiding in dispersal of the spores. **WLK**

TREE SNAILS

A few arboreal snail species are found in our rainforests, but because of their habit, they are often perceived to be rare as they are seldom seen. In fact, it would not be surprising if most visitors to the local forest trails have never seen one. The ecology and diet of the local arboreal molluscs remain largely unknown, and most arboreal snails are believed to feed mainly on microscopic flora, such as lichen and fungi, growing on the surface of leaves and bark. The arboreal ***Trachia* sp.** is one of the rarest terrestrial macro mollusc species in Singapore, and even empty shells or fragments on the ground are seldom encountered. A larger and better known arboreal species in our forests is the Yellow-shelled Tree Snail. Previously thought to belong to the same subspecies as the one described from Perak, Peninsular Malaysia, the **Green Tree Snail (*Amphidromus atricallosus temasek*)** was only recently described as a distinct subspecies. These snails are particularly interesting for the randomly dimorphic coiling of their shells (i.e., an individual shell may coil in either a clockwise and anti-clockwise directions) in a population—a phenomenon not seen in any other species in Singapore. **TSK**

***Trachia* sp.** is one of the most elusive terrestrial snails in Singapore. Size: 17–18 mm.

Not all echolocation calls are inaudible to humans. The **Pouched Tomb Bat (*Saccolaimus saccolaimus*)** has an echolocation call that can be heard as high-pitched 'clicks' by the human ear. These adaptable bats can be heard hunting for insects in forests, over water bodies and even in urban areas. They roost communally in hollow trees, rock crevices and buildings. Size: forearm length up to 78 mm.

THE SOPRANOS

Most insectivorous **microbats (suborder Microchiroptera)** are nocturnal, emerging during dusk to hunt insects on the wing. Contrary to popular belief, they are not blind, although most have small or poorly developed eyes which are used more for navigation than locating prey. Microbats have a special technique known as echolocation which they use for hunting. This works by emitting a burst of sound—some can be very loud with volumes of over 140 dB (sound pressure level) recorded (as loud as a jet engine) —and then listening to the echoes that return from the environment. By interpreting the time delay and the loudness between each call and the returning echoes received by both ears, a bat can tell the distance, direction and even size of objects around it. In addition to finding prey, bats also use echolocation for navigation. This allows forest-dwelling microbats to pick out small flying insects while avoiding branches and leaves when hunting in dense understorey vegetation.

Plants also produce chemicals known as secondary metabolites that are often used for defence. Terpenoids are the largest group of secondary metabolites. Some are volatile essential oils such as those in citronella, camphor, menthol, etc. These protect against bacterial or fungal attack and deter insects. Other terpenoids are found in latex and resins and can be quite toxic to animals.

Phenols are another group of secondary metabolites that plants use to defend themselves against pathogens. These chemicals include tannins, flavonoids, and anthocyanins which give plants their red, blue, yellow, and white pigments. Tannins are the most abundant secondary metabolites made by plants and may take up to 5–10% dry weight of the leaves. They are bitter tasting and decrease protein digestion in vertebrate herbivores by binding to the salivary proteins and digestive enzymes, inactivating these proteins. Tannin is toxic to insects and the toxicity is thought to result from the production of high levels of reactive oxygen compounds when the tannin is oxidised in the acidic environment of the insects' guts.

The cell walls of plants contain lignin, a phenolic compound which makes the cell rigid. Lignin is the main component of wood and is mainly found in secondary cell walls. Lignins are insoluble, rigid and indigestible. Hence, cell walls that are lignified are highly impermeable to pathogens and resistant to insect attacks. There are some cells of plants that store toxic chemicals, silica, or other sharp crystals that deter herbivores from eating the plants. **WLK**

The **Fish Tail Palm (*Caryota mitis*)** has leaflets which resemble a fish tail in shape. The leaves and fruits have calcium oxalate crystals which are needle-shaped and may tear the mouthparts of herbivores when chewed. The crystals are toxic if ingested. Handling parts of the palm may result in a burning sensation and skin irritation for most people. Size: up to 4 m tall.

ARMED & DANGEROUS

Scorpions (order Scorpionida) are an ancient group of arachnids. They are nocturnal hunters of insects, spiders and other arthropods. Most live on the ground. They possess well-developed pincers and a long tail with a bulbous venom gland and forward-projecting, needle-like stinger at the tip. Scorpions have poor vision. When foraging, they feel their way about with a pair of comb-like structures (known as pectines) that project from the ventral part of the body and can gauge both mechanical and chemical signals from the surroundings. Sensitive hairs (trichobothria) on the surface of the pincers can detect any slight disturbance caused by the movement of potential prey or predator. This alerts the scorpion to raise its stinger to get ready for a sudden attack. It is usually only larger prey that receives a venomous sting. Scorpion venom consists of a complex mixture, including neurotoxins, histamine, serotonin, and enzymes. The venom is considered one of the most toxic substances known to man. Fortunately scorpions usually inject only a small amount as the venom is costly to produce and the pincers are usually sufficient for the capture of smaller prey.

Scorpions, such as this **Black Scorpion (*Heterometrus longimanus*)**, are nocturnal. During the day, they seek shelter in the leaf litter, under logs, bark, stones or loose earth. Size: up to 14 cm.

By vibrating its body, a stick insect is able to cause a shaking of the entire small branch and leaves on it, and mimic leaves and branches swaying in the wind. This distracts predators from the actual insect itself. Some species adopt a wild swinging of the entire body and legs when molested as they fall to the ground. Seen in isolation this is comical and one cannot see how the action is protective. In the dense forest undergrowth however, this wild shaking causes all the surrounding leaves and small branches to sway, mimicking the effect of wind blowing through the undergrowth.

Lonchodes brevipes will initially adopt a wild swinging motion but once it drops to the ground it will lie still and play dead until the danger is passed. This again detracts the predator into looking at the swaying leaves to miss the actual insect now lying like a dead twig on the ground. Shown here: an adult female *Lonchodes brevipes* lying against leaves of a local bramble bush.

A female **Leaf Insect (*Phyllium bioculatum*)** looks deceptively like the leaves on the plant it feeds on.

Many stick insects in our forests have green, yellowish or brown bodies, and bright red wings. When disturbed, these insects take flight. All the predator sees is a flash of red. When the insect lands on a branch or leaf it closes its wings again and blends back in with the background. The insect therefore becomes invisible while the predator is still looking for a bright red object.

Most stick insects do not change colours at will. Several species, however, can adopt different colours depending on the plants they feed on. **Leaf Insects** in particular are able to do this. ***Phyllium bioculatum*** are normally green but when reared on leaves of *Syzygium* species, will turn yellow or red. This may be because many *Syzygium* leaves are yellow when old and bright red when young. When reared on a particular plant over a period of several weeks, stick insects can also show subtle colour change.

Caterpillar of the **Oleander Hawk Moth (*Daphnis nerii*).**

THE EYES HAVE IT! The caterpillar of a **Great Mormon (*Papilio memnon agenor*)** crawls on a branch after having its fill of fresh succulent leaves of its host plant—the Pomelo (*Citrus maxima*). The caterpillar features large and intimidating false eyes on its body. It is believed that the eyes serve as a deterrent to a would-be predator that the harmless caterpillar appears much larger and more ferocious than it actually is. At a certain angle, the caterpillar is said to resemble a snake—a creature that a bird would certainly avoid!

Many caterpillars, especially those of swallowtail butterflies, have large fake eyes. What is interesting is the non-directionality of the eyes. No matter which direction you look at the capterpillar, these fake eyes appear to stare back at you. This confrontation tactic presumably stalls the attack of potential predators. The caterpillar of the **Great Mormon (*Papiliomemnon agenor*)** is shown here.

FANCY FUNGI

The familiar mushrooms that can be seen sprouting out from the forest floor belong to a large group of fungi known as **Club Fungi (phylum Basidiomycota)**. Many species are decomposers. These fungi reproduce by sexual means. The mushroom is actually the fruiting body of fungi. Millions of spores can be found within the gills or pores on the underside of the cap of the mushroom. The fruiting body or mushroom will only appear for a few days to disperse the spores; after which the mushroom will decompose. The main body of the fungi lies underneath the ground or hidden in the decomposing matter. The mushroom itself becomes food for many animals, including some insects and mammals.

Thread-like filaments (hyphae) of a fungus spreading out on a dead leaf.

Various types of fruiting bodies can be found in our rainforests. The **Gilled Fungi (Agarics)** often sprout in large numbers on fallen logs after rain. The spores are formed from microscopic club-like structures on the gills. Some Gilled Fungi can be very colourful, sporting a bright blue or orange cap on the fruiting bodies.

Troops of a common Gilled Fungus, the **Parasol Mushroom (*Lepiota* sp.)** fruiting on a log.

The ***Entoloma* sp.** has a deep blue cap with distinct salmon pink gills.

The delicate ***Leucocoprinus* sp.** is another common Gilled Fungus in our nature reserves and often seen singly after rain.

ANT APARTMENTS

Many plants have close links with ants. These include some members of the genus *Macaranga* that have developed obligatory relationships with ants from the genus ***Crematogaster***, also known as **Heart Gaster Ants**. An example is the pioneer plant species, the **Common Mahang (*Macaranga bancana*)**, which is frequently encountered along trails in the rainforests. These plants have hollow stems, which ants reside in, as well as swollen red stipules (modified leaves), which house fat-rich Beccarian food bodies for the ants. Many plant species also attract sap-sucking scale insects, which are, in turn, tended by the ants for the honeydew that they produce. In return for the shelter and food that the plants provide, the ants protect the plants from herbivorous insects or other potential enemies. Disturb an ant-occupied plant, and you will quickly see its 'tenants' swarming out of tiny holes on the hollow stems, often raising their gasters (the rear part of the ant that includes the abdomen) in agitation and squirting formic acid from the ends. The ants may also bite off any parts of a foreign plant from coming into contact with the plants, thus preventing the *Macaranga* plant from being laden with climbers or epiphytes. **WLK**

Common Mahang *(Macaranga bancana)*.
Size: up to 5 m.

The white granules are the food bodies produced on the underside of the stipules of the plant. The food bodies are eaten by the ants.

The **Heart Gaster Ants (*Crematogaster* sp.)** live within the hollow stems of ***Macaranga***. The ants protect the plants from herbivory and climbers. The wastes of the ant colony may also provide some nutrients to the plants.

JUNGLE GROCERY

Tropical rainforests have long provided humans with numerous ecosystem goods and services, i.e., benefits to human well-being. We benefit from some of the services, such as climate regulation, by leaving the forests alone. Some ecosystem goods, however, require exploitation of the forest through harvesting or extraction. Many familiar plant and animal food and medical products, as well as other useful materials, are associated with rainforests, having actually been derived or originated from species within. Although Singapore's rainforests are now no longer exploited, they still contain many species of plants that used to be exploited here or continue to be exploited elsewhere. This chapter highlights a few examples.

JUNGLE PRODUCE The rainforest is a source of food and produce. The major forest product is timber and these come mainly from the tropical rainforests. One major plant family, the Dipterocarpaceae, supplies most of the tropical hardwoods. These include Mersawa (*Anisoptera*), Keruing (*Dipterocarpus*), Kapur (*Dryobalanops*), Merawan (*Hopea*), Meranti (*Shorea*) and Resak (*Vatica*). Rattans make up the most important secondary products. These are the fiercely climbing palms of the genus *Calamus* that supply the cane furniture trade. Bamboos (*Bambusa*, *Dendrocalamus* and *Gigantochloa*) are another minor product, traditionally harvested for building materials but now more and more find their way into paper making, parquet, plybamboo and as a canned vegetable in the form of bamboo shoots or *rebung*.

Most of the hard wood timber comes from the rainforests in Southeast Asia. Vast expanses of rainforests have been logged to meet the demand for good quality timber.

Rattans are collected, stripped of their thorns and made into cane furniture.

Indigenous people in Southeast Asia harvest the 'cabbage' of many palms to be eaten as vegetables.

Palms such as *Arenga pinnata*, *Borassus flabellifer*, *Caryota urens* and *Nypa fruitcans* are tapped for sugar or palm wine, with the growing point, commonly known as cabbage, eaten as a vegetable by indigenous people. *Metroxylon sagu* is exploited for the starch obtained from the pith of the trunk. Palm leaves are used for thatching, weaved into mats and baskets, while the leaf midrib made into brooms.

Numerous plants of ornamental potentials are being introduced to gardens. These include selections of palms like Lipstick Palm (*Cyrtostachys renda*) and Diamond Joey (*Johannesteijmannia altifrons*). Many species of gingers and orchids have also been introduced into cultivation, the latter used in breeding. **WYC**

Many vertebrate animals of the rainforest have been reported to be locally extinct in Singapore. However a large number of these old records were not based on specimens that were unequivocally obtained from Singapore. The species presented here were known to exist in Singapore from specimens collected with detailed locality data in the past, or from confirmed historical records.

(Left): **Cream-coloured Giant Squirrel (*Ratufa affinis affinis*)**. This distinctive arboreal rodent, the size of a small cat with a very long and bushy tail, has not been seen in Singapore since the mid 1990's. Two individuals used to roam the forest south of the Upper Seletar Reservoir, and both are believed to be the last of their kind in Singapore. Size: head and body 310–360 mm; tail 385–415 mm.

Striped Cave Racer (*Orthriophis taeniurus ridleyi*). This handsome snake grows to around 2 m, and is often associated with caves where it ambushes bats and swiftlets. After a juvenile example was obtained on Pulau Ubin in the 1920's, none has since been reported from Singapore. This snake was photographed at Taman Negara, Malaysia.

The local extinction of forest specialists in Singapore has seen not just the loss of species, but in some cases, the loss or decline of entire taxonomic families. Two families of forest birds have suffered total loss in Singapore, the **trogons (Trogonidae)** and **broadbills (Eurylaimidae)**. This is followed by **woodpeckers (Picidae)** and **hornbills (Bucerotidae)**, which lost more than half of their species. The disappearance of the **Rhinoceros Hornbill (*Buceros rhinoceros rhinoceros*)**, along with the scarcity of **Green Imperial Pigeon (*Ducula aenea polia*)**—both frugivores—from our forests is likely to have had significant ecological consequences for trees that bear large fruits for bird dispersal.