Ekspedisi Saintifik Bukit Fraser 2010

The physicists Prof. Ille Gebeshuber and Tina Rezaie Matin, MSc., from the Institute of Microengineering and Nanoelectronics (IMEN) at UKM, as well as the two Biomedical Engineering students Jennifer Bawitsch and Teresa Stemeseder, from UAS Technikum Vienna, participated in a Mini-Expedition to Bukit Fraser in February 2010. Together with fifteen other participants, mostly from the Department of Biology at UKM, we experienced three days full of joy and inspiration. The group of scientists stayed at the UKM Research Station and conducted several excursions into the heart of the tropical rainforest. While for the two practical students from Vienna the trip was mostly an adventure as it was their first encounter with the jungle, Prof. Ille and Ms. Tina applied the Biomimickry Innovation Method[1] (BIM).

During our walks in the forest we came across many unique subjects inspiring us to do further research and give deeper thought to. The following pictures are only a few examples that are worth sharing with other scientists.

Figure 1: Dr. Fazli and his team looking for spiders

On our hunt for tarantulas in the first night of our stay we were looking for holes in the slope along the road that would present the entrance of the spider's den. After being successful in finding those, many pictures were taken (Figure 1). Once the night active spiders come out of their den, they are easily detectable due to their reflective eyes. Investigating this property could help improve reflectors in industry, especially concerning microreflectors. How frequently reflectors are applied is also illustrated by this picture since the cap of one of the participants shows great reflectivity. Caps are not the only textile where reflectors are applied in order to enhance security other examples include security vests, protective clothes and so on. However, reflective tools or materials are of increasing importance and interest for wide ranges of applications.

[1] For further information on the Biomimickry Innovation Method see "Ekspedisi Saintifik Lata Jarum 2009" by Prof. Ille Gebeshuber and Tina Matin Rezaie, MSc.

Figure 2: A tarantula staring at us, revealing its reflective eyes

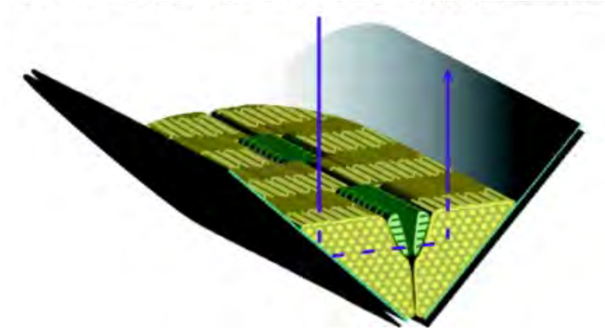

Figure 3: Drawing of the 'canoe-shaped tapetum' of *Drassodes cupreus* and the retina, with one possible path of light through the eye (arrow). The front end of the eye is cut off to expose interior structures.[2]

After one tarantula was lured out of its den the photograph shown in Figure 2 was taken. Luckily the reflections of the eyes were beautifully captured. Reflections like these can only be observed when looking at night active spiders and since the reflections are very directional, standing in a certain position towards it. Due to this property even the person standing next to you might not be able to get the same impact as you do. Reflections of the eyes of animals are caused by the *tapetum lucidum,* which is a reflective layer located behind the retina. The rectangular arrangement of the layer (Figure 3) causes the incoming light to be reflected parallel and can therefore only be seen when the observer is positioned in the same angle as the light source.

Figure 4: Land crab found on Bukit Fraser

The animal in Figure 4 was first thought of as a spider in a shell, because it surprised us to find a land crab at Bukit Fraser. Normally land crabs live in tropic coastal regions since they use the sea as their

[2] Modified from Dacke, M., Doan, T.A., O'Carroll, D.C, 2001. *Polarized light detection in spiders*. The Journal of Experimental Biology, 204, 2481-2490.

preferred location for egg deposition and their larvae develop there. Hence, there is one species of land crab that lives at a distance to the sea of about 8 km. This is still not comparable to the one we found in Bukit Fraser due to the fact that approximately 70 km separate the location where we found it from the sea. There are some fresh water spots in the nearer surroundings, such as the Jeriau waterfall, but fresh water land crabs are rare. Although there are only about 20 species of land crab, we were not able to find one similar to ours in order to determine it until now.

Figure 5: Orchid Mutiara, a very small orchid, found on Bukit Fraser

Orchid Mutiara (Figure 5) belongs to the rare group of jewel orchids. Unlike most orchids with beautiful flowers, they are famous for their leaves. Its leaves show remarkable patterns and shininess. Malaysia is one of the few countries, besides India, Japan, Sri Lanka and Indonesia, where one can find jewel orchids. We were very lucky to encounter the Mutiara several times along the paths and therefore even without requiring any painstaking quests. As jewel orchids like to grow in a very humid environment and too much light harms them, the rainforest is a perfectly fine surrounding. Since you can provide those conditions in your bathroom, they can be gardened easily. This is why the Mutiara is quite favored by hobby gardeners and orchid lovers.

Figure 6: A caterpillar climbing up a twig

Using colors and mechanical tools as protection is a common thing in the animal world, as shown by the little caterpillar in Figure 6. Its red head may symbolize an inedible berry and therefore seem unattractive to other animals and prevent them from eating it. The hair on its back looks like dangerous stings, another reason to keep a certain distance to the caterpillar. Although we did not examine whether the stings were hard or soft, they appear to be painful. Mechanical or color-coded protection is always directed against the most dangerous threat, meaning that the stings of this caterpillar will repel its natural enemies such as birds or spiders, but not other animals.

Figure 7: A small plant with pink spurs.

The plant in Figure 7 was also observed during the last expedition (Lata Jarum 2009) and attracted the interest of our group again. Tiny pink spurs grow on the leaves and their color changes due to a leaf color substrate, the curvature of the leaves and even the angle of viewing. In various areas with different climates the plant was detected with dissimilar size and thickness. Near the camp and close to the road they were found small with thin and soft leaves, whereas inside the rainforest one specimen of about 1.5m in height, thick leaves and purple spurs was recorded. The origin of the pink color remains unknown to us but it would not surprise us if the spurs offered certain structures to produce structural colors. Another question to be considered is what the benefit of having the spurs covering the whole plant body is. It inspired us from both structural and functional perspectives.

Figure 8: Tina R. Matin is taking a picture of something that attracted her interest

As a person who is interested in Biomimetics one can find things that capture your attention in any possible surrounding. The only important thing is to pay attention and take your time and then even the smallest plant or animal will catch your sight and may inspire you. Besides by doing so you will get the opportunity to take unique pictures of the most exotic motives. As Figure 8 shows, Tina even found something remarkable that was worth taking a picture on a completely inconsiderable plant. Although this site is located only a stone's throw from the UKM Research Station the whole group but Tina passed it, without noticing anything meaningful.

Figure 9: Plant, offering very regular lines and expandable shapes on its leaves.

While looking for different functional levels, this leaf with its regular channels and expandable shapes drew our attention to it (Figure 9). The regular lines can lead water during rainfalls either to the ground or to the stem. The ability to cause flexibility by building three-dimensional structures out of two-dimensional surfaces is one of the most applied approaches in engineering and design science currently.

Figure 10: The Pitcher plant. Top: Two different species of Pitcher plants found on Bukit Fraser. Bottom left: Internal space of the plant, its door was held open by one of the researchers. Bottom right: Scientific gardening of Pitcher plants.

"Plants can offer a model for imitation. Besides their familiar characteristics, some plants exhibit actuation capabilities that are expected from biological creatures. Such plants include the […] bug-eating plants with a leaf derived trap "door" that closes and traps unsuspecting bugs that enter to become prey."[3] One example of these plants is the Pitcher plant, *Sarracenia purpurea* (Figure 10). This plant, known locally as periuk kera, is one of the famous carnivorous flowering plants.

The plant does not move to catch animals. Although the pitchers origin from leaf organs, they are not leaf-like. "Nepenthes pitchers are organized in a complex way, with a lid, a peristome (a ring around the pitcher's entrance), and slippery and digestive zones, the latter containing a supply of digestive fluid. These pitchers draw in insects, hold them, and finally digest them."[4] The inside area of this plant is covered with two structurally different layers of crystalline wax. The top layer consists of about 30-50 nanometer thick platelets contaminating the insects' feet and making them less adhesive. The lower layer reduces the contact area between the feet and the trap.

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[3] Bar-Cohen, Y., 2006. *Biomimetics: Biologically Inspired Technologies*. Boca Raton: CRC Press Taylor & Francis Group, p. 5.

[4] http://merlinq.nl/index.php?option=com_content&task=view&id=239&Itemid=74 [4.3.2010, 14:30]

Figure 11: The expedition group standing in a huge fern

When entering a tropical rainforest it immediately leaps to the eye that everything is bigger than in other environments. Even the ferns which are known in Europe as knee-high plants can reach heights exceeding a man's size (Figure 11). It seems as if the tropical forest offers a climate that suits extreme magnitudes in many forms, for example the world's biggest moth, which will be subject of this report later on. Furthermore the speed of growth is admirable, as we have seen at the Forest Research Institute Malaysia (FRIM) that a whole rainforest can grow within 80 years.

Figure 12: Dry plant, reminding of ribs

We found this dry plant (Figure 12) while we were looking for inspiration; it can be used to hold materials and objects. It seems that some parts of nature, in addition of having applications in their lifetime, stay useful after their death but with different shape and obviously different applications. The current shape of this plant reminds us of ribs and their protection role of creature's hearts. It inspires how to build disposable lock spaces because of the dry and fragile wrapping leaves. With some structural changes for example making it more flexible, the area of applicability will expand. Another interesting thing about the plant's body is its form and the same directional curvature of all leaves.

Figure 13: Leaves of a Mimosa

The Mimosa is a small, weedy plant with leaves like ferns (Figure 13); sensitive to any touch it drew our attention to it. Different parts of the plant have different sensibilities; in more tiny leaves, even a puff of wind can close them. Also the speed of reaction varies with the region of the plant; touching a junction on the stem results in the leaves on it folding very fast, while touching the single leaves folds them slowly but still in a coordinated manner. They also close during the night, maybe because they are sensitive to light intensity. As we learned from Dr. Fazli, the Mimosa folds and closes its leaves by relocating the liquid components from the leaves into the stem. The whole plant is a fabulous gathering of sensors. The sensitivity and fast reaction of this plant to any kinds of touching is amazing from an engineer's point of view and investigating the mechanisms can lead to models for some mechanical machinery systems in high speed industries.

Figure 14: Three interesting structures found in the rainforest; a reddish, young leave, an older leaf and a fern in the background.

Still looking for symmetry in nature we encountered this motif. Figure 14 illustrates three symmetric shapes and structures. The young reddish leaf measured against one of the researcher's hands, shows beautiful symmetric structures. Because of the young age of this leaf it is not completely open, forming a tube the front and backside are close to each other and we have the opportunity to compare them. The leaf is not green yet but it demonstrates two different shades of red. The color variation of leaf sides is one of our group's case studies. Leaf veins make a gorgeous pattern that is the best water and nutrition supply system. We can also mention that the backside is more responsible for food delivering because of the higher number of branches. This structure can be used for providing information about networks covering wide areas or even for water pumping systems for gardening applications amongst others. The flat old leaf uses two main veins because of the wide surface and probably weak main veins. The fresh fern in the background presents one of the greatest natural symmetric patterns.

Figure 15: Prof. Ille disappearing in a huge fern

Figure 16: Croziers

Figure 15 shows another good example for the magnitude of plants in the jungle. The fern covered Prof. Ille as a whole when she tried to get a closer look at a newly developing frond. The spiral next to Prof. Ille's head is called a crozier or fiddlehead. By unrolling it enables the young leaves to reveal themselves and expand.[5] Croziers can reach remarkable heights and are often found freestanding as well as apart from others, which is why they leap into the eye immediately (Figure 16).

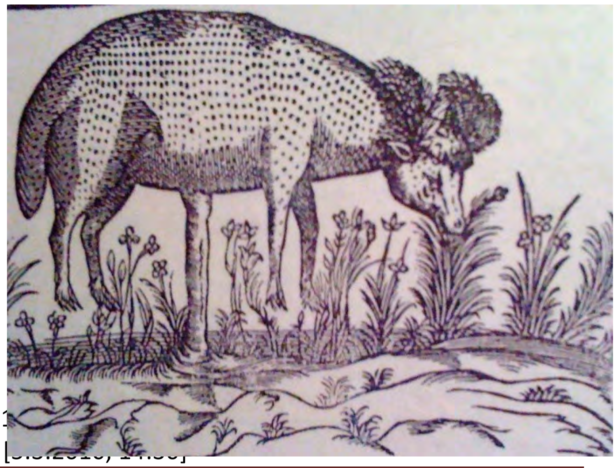
Figure 17: Different levels of a fern's development.

Cyathea brownii, the largest species of fern, is 20 m (66 ft) or more in height and probably originated from Norfolk Island. Our team of researchers from the engineering department encountered many different fern species both big and small in Bukit Fraser. Nevertheless, the size or names of the species were not the most attractive characteristic for us. Watching the different periods of a fern's life was very inspiring for all of us. Ferns permanently exhibit symmetry in nature as they present this characteristic throughout each and every stage of development (Figure 17).

[5] http://en.wikipedia.org/wiki/Fern

Figure 18: Cibotium barometz, also referred to as Golden Chicken Fern

As the trunk of the fern *Cibotium barometz* shows a special kind of hair which, when the branches are cut off, has a certain similarity to a roasted chicken, it is also called Golden Chicken Fern (Figure 18). That kind of hair only appears in this specific species of fern and hence is sold as a souvenir for tourists in markets at Cameron Highlands (Figure 19). In medieval times it was believed that sheep-like animals grow out of the golden trunk and were the origin of cotton, as the drawing in Figure 20 shows. *Cibotium barometz* grows in China as well as in parts of the Malay Peninsula and its hair is often used by locals as a styptic.[6]



[6] ... 201
http://en.wikipedia.org/wiki/Vegetable_Lamb_of_Tartary

Figure 21: Our guide, Mr. Shukri, leading us through the thicket

In the dense vegetation of the tropical rainforest it is of high importance to have an experienced guide with you. In our case we had Mr. Shukri from the Forestry Department of Pahang with us, who made the path accessible using his machete. Although we intended to stay on the trail where we might not have needed a ranger, a fallen tree which blocked our way, forced us to leave the path. Because of unforeseeable events like this it is always advisable to be accompanied by a person who knows the forest and its dangers. Though the jungle seems to be overwhelmingly powerful it must not be forgotten that it is vulnerable at the same time. Hence it is of utmost importance to preserve and protect the rainforest including its variety of species. Clearing has to be held in a reasonable extent since even though the forest grows back rather fast, a small patch of jungle won't be able to sustain.

Figure 22: The expedition group is relieved after finally exiting the jungle

Figure 22 shows the research group finishing the jungle trail, exhausted but happy. The picture also shows very distinctly the transition between bright and dark regions caused by casted shadows and the resulting diversity of vegetation. Normally the canopy of a healthy rainforest is almost closed and allows very little light to reach the ground. Whenever a tree falls and an opening in the canopy results, the sudden amount of light getting through gives other species of plants a chance to shoot up. This process of recolonization follows a strict order, starting with fast growing plants that provide a suitable environment for later sprouting plants. The *Macaranga* tree for example, reaches remarkable heights in a short period of time in order to cast shadows which help other plants to develop. After years of recolonizing, the gap in the canopy is closed again.

Figure 23: Mr. Shukri removes rattan spikes with his machete

Figure 24: The spikes of Rattan follow a distinct hierarchy

Our guide carefully removed spikes of rattan from Jenny's hand (Figure 23) which she had gotten in her fingers earlier by accidently grabbing a trunk. He did so by scratching with his machete lightly over the hand. Rattan has this elaborate system of spikes in order to protect itself from herbivores as

well as to climb. The spikes can be found everywhere on the plant, from the trunk to the branches and the leaves. Their number and form vary depending on their location and they build up in a hierarchical system. Hierarchy is a very important element in nature since it often leads to extraordinary properties such as stability or in our case effective defense mechanisms.
Due to a functional adaptation of the structure at all levels these remarkable properties arise. Functional adaptation consists of two parts, on the one hand adapting the form, on the other adapting the microstructure of the material itself. This dual optimization is the recipe for solving many problems in engineering. Concerning nature, material's microstructure and shape are closely related since the growth of the organ means a common origin.[7] Natural growth is the one big advantage that nature has over engineers. Nature builds its structures by starting at the very bottom through assembling on a molecular basis whereas humanity mostly builds its system by putting together already completed parts on the macroscale. This is the reason why fine tuning is so hard for scientists while it is so easy for nature.

Another example for perfect hierarchy can be seen in Figure 25 which shows a young fern with its coils on several levels. Due to the regularity of the formation of hierarchy it is possible nowadays to easily code these processes and hence to simulate them.

Figure 25: A young fern, showing highly hierarchical structures

[7] Fratzl P. and Weinkamer R. *Nature's hierarchical materials*. Progr. Mat. Sci. 52 (8) (2007) pp. 1263-1334

Figure 26: Left: Rattan fruits, Right: Rattan leaves, both showing different kinds of symmetry

Following the symmetry in leaves, we can consider the other parts of plants also. Here we can see two kinds of symmetry, one in the tree's branches, and one in the fruits. Rattan is one of the most successful presenters of symmetry in nature, since it is found in their main body, leaves, branches, and even their fruits. Regular distances between the junctions present bilateral symmetry while the spherical fruits clearly show radial symmetry.

Figure 27: Panoramic view from walking along the Pine Trail in Bukit Fraser

Bukit Fraser is situated in the Titiwangsa Mountain Range in Pahang. In order to reach it, one has to follow a single-lane serpentine road for thirty exhausting minutes. Nevertheless, the view over the area (Figure 27) is quite rewarding and gives one the impression of almost infinite width. What can be seen in the centre of the picture is the helicopter landing site, for those who are more privileged and enjoy a game of golf in the cool heights of Bukit Fraser. Besides the golf course there are several other facilities for visitors with less interest in adventurous hiking such as comfortable accommodations and luxurious restaurants.

Figure 28: Measuring the size of a night active spider

During our night trips, the main goal was to find night active spiders, capture their reflections and measure the maximum distance of visibility. The same investigations were done earlier in Lata Jarum 2009 by Prof. Gebeshuber and Tina Matin. Therefore the two of them had much more experience in locating the spiders; especially Tina who could track down even the smallest individuals. We, on the contrary, not only had some difficulties in finding them, but also taking measurements and photos were big challenges. Unfortunately it happened more than once that a spider of perfect size and with beautiful reflections simply ran away or turned its back on us. Despite all these burdens we finally collected two or three useful results and definitely learned a lot that will help us to be more successful next time.

Figure 29: The atlas moth, *Attacus atlas*, the biggest moth worldwide

When we returned from our night walk, we got the opportunity to take a closer look at the world's biggest moth, *Attacus atlas*, which was attracted by the light of our station. The moth has very big and highly sensitive antennae which allow single-molecule detection; for example in order to let male moths find female individuals for mating. Our illuminated station attracted a large number of butterflies and other moths, although the reason for this attraction could not be clearly explained to us. We presume that butterflies and moths orientate using moon or starlight and simply mistake the artificial light. As the illuminated night sky is not only a danger for attracted insects but also seems to be unhealthy for humans, there have been founded a few organizations that fight for a dark night sky. (For further information see http://www.darksky.org or http://www.savethenightsky.com)

Figure 30: One of the moths attracted by the light

Due to the variety of species, Bukit Fraser has a very high potential for studying moths and insects. As mentioned earlier, our light sources attracted hundreds of them to the camp. They lay under the light without any movement and left the site about 11 in the morning. Beside our theory of the moths mistaking the lamps as their orientation system, other ideas came to our minds. The moths may use the light as a source of energy for activities. Another theory says that they meet at light

sources or illuminated spots to find partners for mating. The fourth thought was that the moths may normally rest in daylight; hence they mistake the lamps for the sun and lie down.
Symmetry in wings, body, and antennas is evident and has been discussed by scientists for decades. The interesting thing concerning the moth in Figure 30 was actino-morphic symmetry on its wings which could clearly be detected because of the shiny color of the pattern on the surface. Furthermore, this hairy moth's body shows both outside and bilateral symmetry.

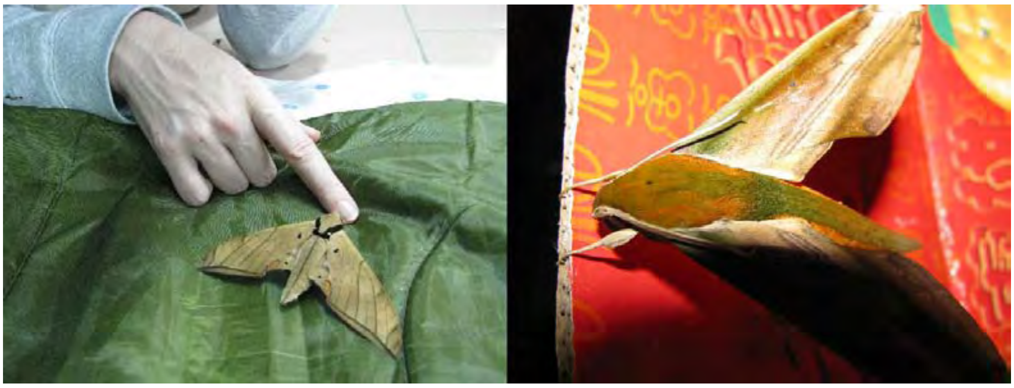


Figure 31: Moths landing near the light sources

The moths being attracted by the lamps were flying very close to any light sources or shiny items. As seen in Figure 31 (left) this moth landed on the sleeping bag because of its reflection or for camouflage reasons. It stayed for almost three hours and we had to move it out of the accommodation to a safer place. In the picture on the right a moth is clinging to a box and wouldn't leave. Its feet are highly suited for holding and balancing weight for long time periods. Also its coloring and patterns are worthy to note.

Figure 32: Swallow-tailed moths were also amongst our visitors in the evenings.

The swallow-tailed moth (locally referred to as *kupa-kupa*) has also a considerable size. It presents bilateral and outside symmetry. One of them was found dead and collected. Having a look under the 3D laser microscope its scales and structures were investigated. Another interesting thing about moths, in addition to their color variety and symmetric patterns, are the nanostructures on their eyes that lead us to technical applications e.g. for producing anti-reflective surfaces. “Some insects benefit from anti-reflective surfaces, either on their eyes to see in low-light conditions, or on their wings to reduce surface reflections from transparent structures for the purpose of camouflage. Anti-reflective surfaces are found, for instance, on the corneas of moth and butterfly eyes and on the transparent wings of hawkmoths“[8].

Figure 33: A beautiful spider web after rainfall

The spider web in Figure 33 attracted our attention not only because of the dew caught in it but also due to the colorful berries it covered. The shiny red fruits stand out of the evergreen surrounding environment. A spider’s web is usually constructed of different kinds of silk threads; some are used by the spider itself to move across the web, while others are sticky in order to catch the prey. The way the web is built provides stability and suits the spider’s size perfectly, referring to its locomotion. The tensile strength of spider silk exceeds the one of steel and is as strong as aramid filaments such as Kevlar. At the same time it is much more elastic and light weight, which makes mimicking spider silk very desirable.

[8] Parker, A.R., Townley, H.E., 2007. *Biomimetics of photonic nanostructures*. Nature Nanotechnology, 2, pp. 347-353.

Figure 34: Balanophora, found on Bukit Fraser, Pine Trail

The Balanophora (Figure 34) is a parasitic plant with a variety of hosts which are normally trees. In total there are six species of Balanophora in Peninsula Malaysia and five in Sabah. It is related to the famous Rafflesia and also very rare. Therefore it took us two attempts to find it but finally we encountered the plant at two different locations. Prof. Jumaat collected one and took it with him in order to examine the plant's spores.[9]

Figure 35: A butterfly found on Bukit Fraser, mimicking insects on its wings
© Johari Jalinas

The butterfly shown in Figure 35 seems to mimic black shiny insects with red heads on its wings. The reason for this coloration is obviously protection against enemies but to us it remains unclear how

[9] Latiff, A., Abdullah, M., Ahmad, N., Adam, J.H., 2009. Bukit Fraser – Crown of the Titiwangsa Range. Bangi: Universiti Kebangsaan Malaysia.

the imitation works. One probability is that the insects shown seem unattractive to the butterfly's enemies, hence they are inedible due to their toxicity or taste. Another theory of ours is that the insects imitated belong to the group of natural enemies and suggest that the butterfly is already being eaten, like a sign saying "occupied". Close to this explanation we thought of the insects being some kind of scavengers since the butterfly shows brown stains that could hint at ongoing decay; telling its enemies that this butterfly is not worth falling prey to. All these strategies would empower the butterfly to stay alive but in fact we don't know for sure which tactic is the conducted one.

Figure 36: The rainforest during the early hours. The fog arose after heavy rainfalls in the night.

We encountered the scenery shown in the photography above (Figure 36) on our search for the Balanophora on the Pine Trail in Bukit Fraser. After heavy rainfalls during the night, dense fog arose from the forest and remained until nearly midday. The impression reminds strongly of the mossy forest found at Cameron Highlands near Gunung Brinchang, located approximately 100km from Bukit Fraser towards the north. Due to the cool and rainy climate in this region the mosses and lichen represent a majority of the vegetation. Trees are normally smaller and have thicker stems than in other environments owing to the reduced sunlight. Since conditions like this are very rare in Malaysia a huge variety of characteristic animals and plants can be spotted only at Cameron Highlands.

Figure 37: The group of students and professors attending the expedition

The picture in Figure 37 was taken in the last evening before our departure from Bukit Fraser. The whole group assembled in order to take one last souvenir photo. Most of the participants are from the Department of Biology at UKM, where they are doing research on biodiversity, ecology and entomology as well as on taxonomy. In the middle of the second row one can find the four engineers who wrote this report. One of the rangers who guided us safely through the jungle is kneeling in the first row on the left. Next to him is Prof. Jumaat, the organizer of the expedition, whom we would like to thank dearly for his efforts and giving us the chance to explore this overwhelming environment.

We spent three very unique and exciting days together with wonderful people in Bukit Fraser.
Thank you!

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