The Enchanted Jungle

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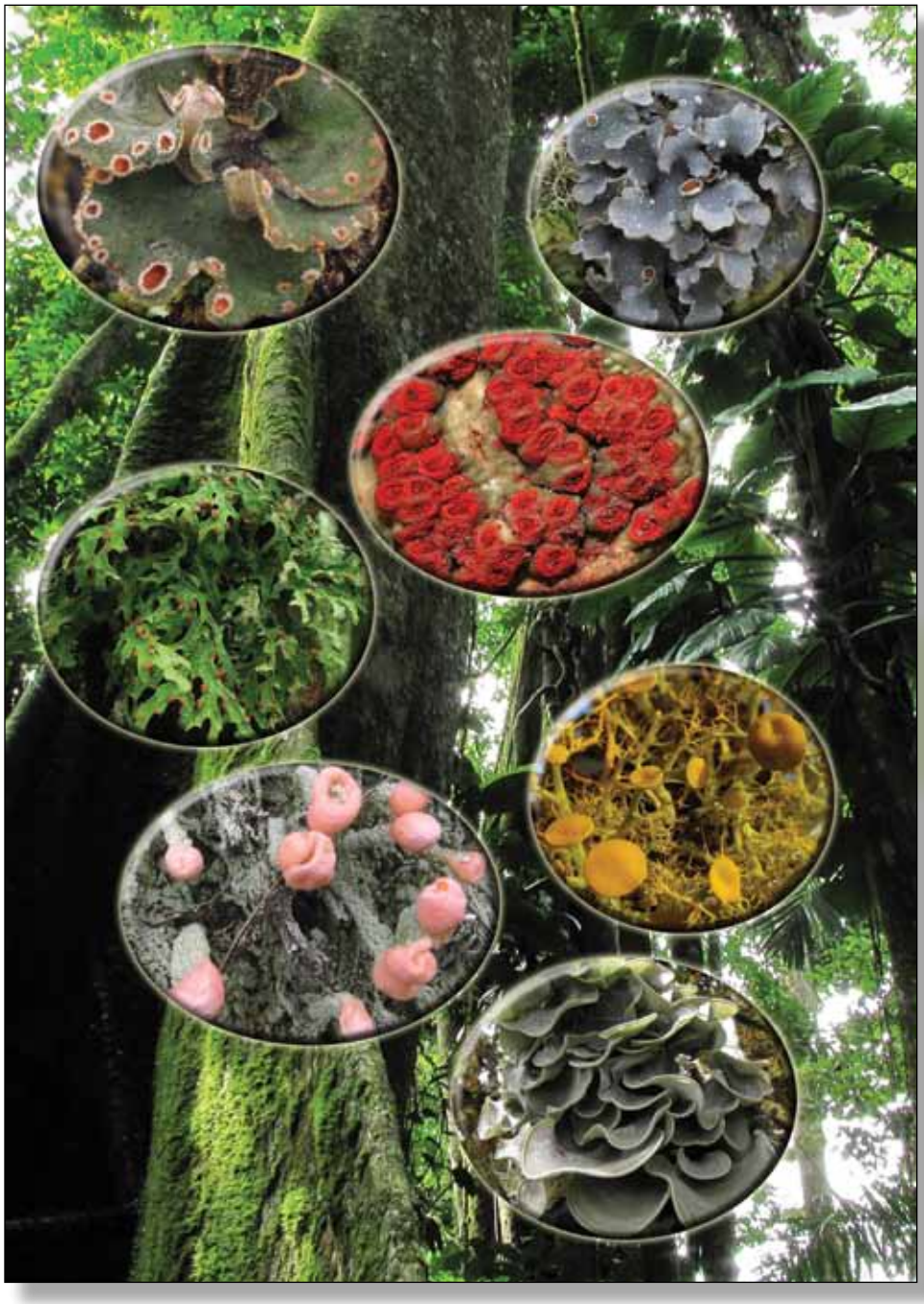

Figure 1. Tropical ecosystems harbor a high diversity of lichens. In the picture: *Sticta gyalocarpa*, *Lobariella sipmanii*, *Marcelaria purpurina*, *Sticta laciniata*, *Teloschistes exilis*, *Dibaeis columbiana*, and *Cora aspera*. Photos R. Lücking.

There are many things an adventurous natural history explorer would want to spot in a tropical jungle. Lush green and winding lianas, colorful flowers and butterflies, birds and bugs, for the most lucky ones perhaps even a jaguar or tiger. Lichens are certainly not among the expected menu. Much less when the most adventurous head out at night with a flashlight, hoping to discover snakes and frogs and other creatures coming to live. Yet, a novel night tour created by a team of researchers at Las Cruces Biological Station in southern Costa Rica, entirely devoted to lichens, has generated more "aaahs" and "ooohs" and even "wooows" among observers than among birders spotting the resplendent Quetzal in Central American mountain forest.

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High Lichen Diversity In The Tropics

Lichens are a unique consortium between fungi and photosynthetic algae or cyanobacteria. They are the most successful symbiosis known in nature, with nearly twenty thousand different species and with diverse morphologies not known from the individual partners. Until most recently, it was believed that lichens escape the general pattern of organisms becoming more diverse towards the equator, and regions such as the tundra or alpine environments were cited as the best spots to enjoy lichen diversity. In tropical latitudes, lichens were mostly expected to be found at high altitudes, which are indeed home to a wealth of conspicuous macrolichens. Yet, research conducted in the last twenty

years, mostly by specialists in North America and Europe, has proven just the opposite. The highest species richness of lichens is found in the tropical rain forests around the world, with up to six hundred species per hectare in extreme cases reported from Costa Rica. Las Cruces Biological Station is one of them. This means there are more lichen species than tree or bird species in any given area of tropical jungle. And no extratropical region can count that many species within a comparably sized area. Apparently, contrary to usual belief, there are many lichens that like it hot, wet, dark, and sweaty.

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Although tropical lichens are as colorful and morphologically diverse as their temperate cousins, or even more so, their diversity in a tropical rain forest is not immediately obvious. Upon entering the jungle, one is faced with endless shades of green and brown from leaves and tree trunks. But even other elements such as flowers, birds and critters are not easy to spot at first glance, and one needs to develop a keen eye for them. This is even more true for tropical rain forest lichens, which are often small or camouflaged, but once detected, they seem to cover every available surface, from tree trunks to branches and twigs, soil and rocks, and even the surface of living leaves. In fact, those leaf-dwelling lichens make up half of the lichen diversity in tropical rain forests, and their small-scale diversity is mind-blowing: up to 50 species have been reported growing together on a single leaf the size of a hand!

The other reason why lichen diversity is not immediately obvious in a tropical jungle is because many lichens are not recognized as such. The phenomenon of fast growing pioneer trees, such as *Cecropia*, having white bark is well known, but contrary to what most people believe, the white bark is not from the tree itself, it is a cover of crustose, mostly sterile lichens. Because of their uniformity and lack of special structures, these lichens are even neglected by versed specialists, but

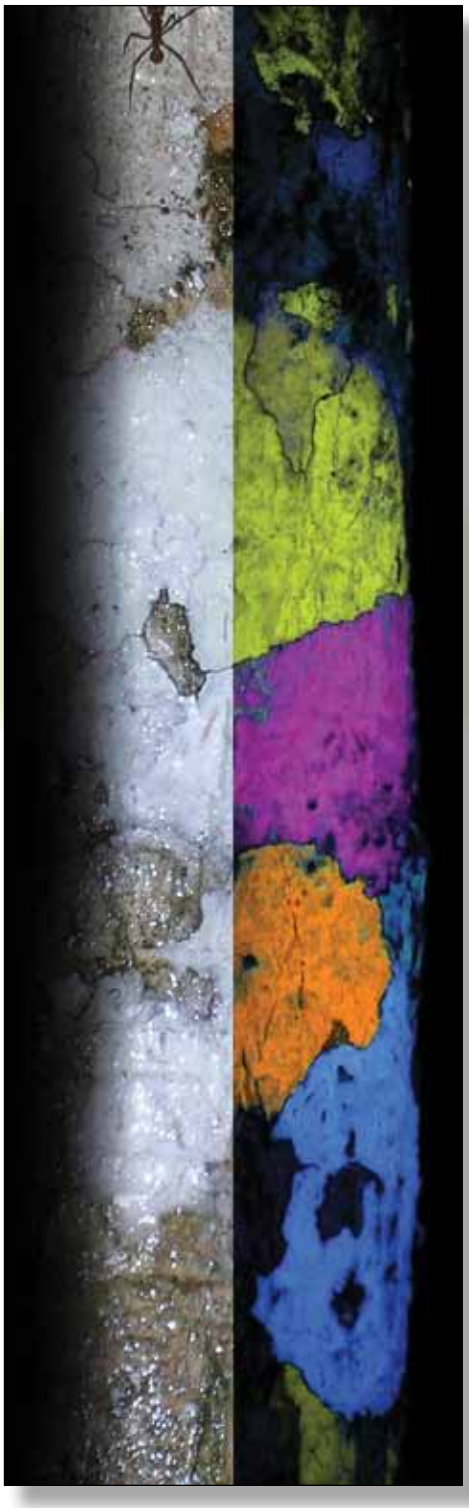

Figure 2. Stem of a small tropical tree at Las Cruces Biological Station in Costa Rica, photographed at night under normal light (left half) and under 354 nm long-wave UV light (right half). Photos R. Lücking.

studies have shown that they not only harbor unprecedented and undiscovered species richness but also are promising subjects of pharmaceutical research, due to their often unique chemical compounds. And here is where the "aaahs" and "ooohs" come in: while these lichens might seem boring in daylight, at night time and equipped with a flashlight and a special ultraviolet light source, they reveal their secrets.

Glowing In The Dark

The first experience looking at white, boring lichens in the night with a UV light is mind-blowing. What looks like white paint during the day, suddenly glows in the most diverse colors, ranging from bright yellow and orange to neon blue, turquoise, green, pink and purple. The colors seem to be everywhere. And each lichen seems to have a different glow. After a while of staring in disbelief, then slowly accepting what one is seeing, and then going around with the UV light to look at these lichens in more detail, more and more subtle colors and even color patterns are detected. The variations seem endless. There is no more conclusive evidence that what seems to be a single lichen during the day, is actually many different kinds of lichens.

So what makes these lichens glow? The explanation is as simple as it is mysterious. Almost all lichens produce some sort of secondary compounds, chemical substances that are produced outside the primary metabolism of the organism and hence are different in different kinds of lichens and fulfill specific purposes. Such secondary compounds are not unique to lichens, they are also very common in other fungi, plants, microorganisms, and even animals. However, they are better studied in lichens than in any other group or organisms, owing to the fact that they are routinely used to actually identify lichens to species. More than a thousand substances have been detected in lichens, and many of them have properties that make them interesting for applications in pharmacy and medicine or to produce perfumes and dyes. What they actually do in the lichen is not known in many cases, but certain compounds act as sunscreens, protecting the lichen alga or cyanobacterium within the lichen from too much UV radiation that could damage the photosynthetic apparatus. Ultraviolet is at the short wavelength, high energy spectrum of electromagnetic radiation, between 10

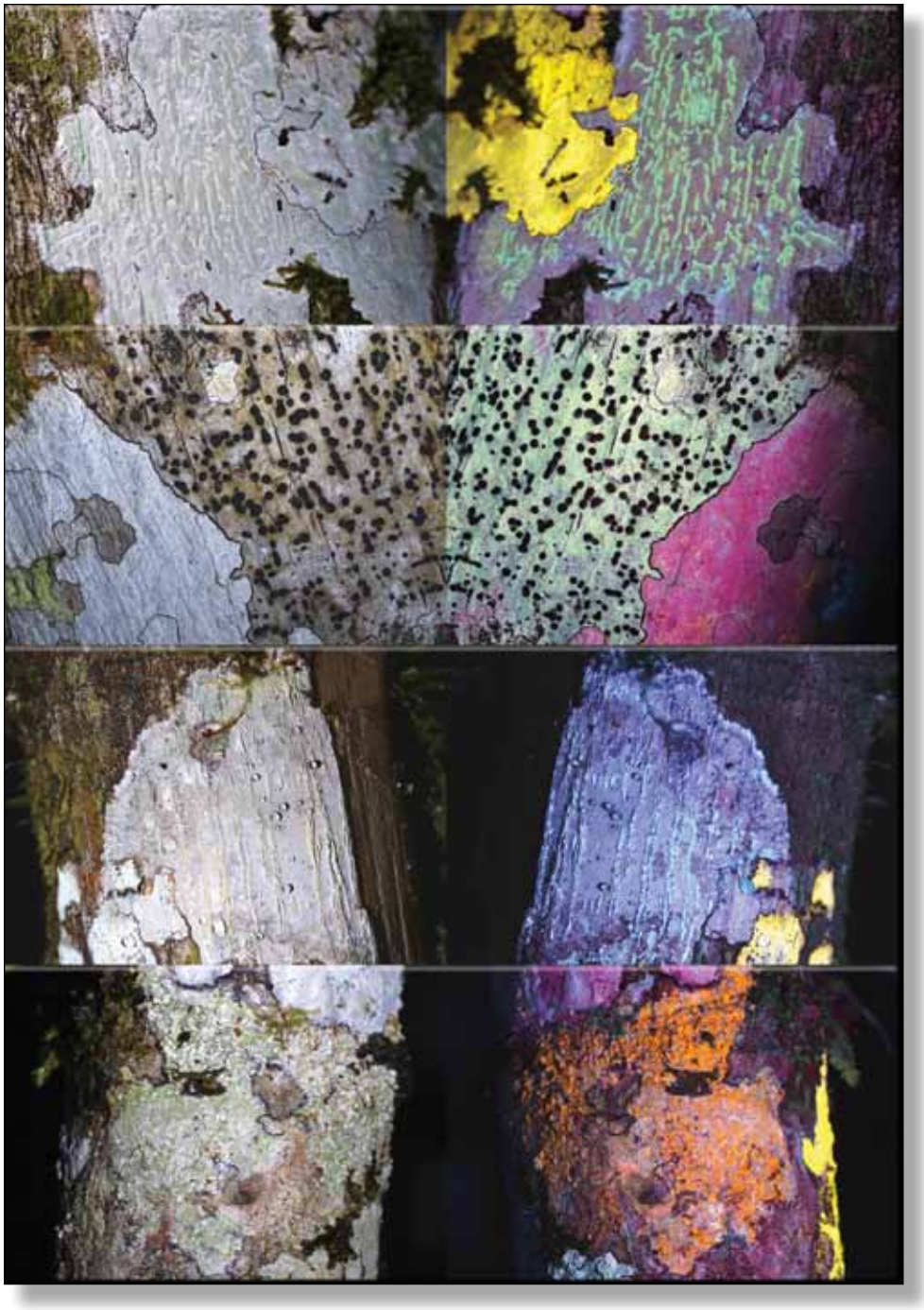

Figure 3. Bark-dwelling crustose lichens at Las Cruces Biological Station in Costa Rica, photographed at night under normal light (left) and under 354 nm long-wave UV light (right, mirrowed). First row: *Diorygma confluens* (UV yellow thallus) and *D. poitaei* (UV green fruiting bodies). Second row: Pyrenula sp. (UV pale green) and unknown crust (UV pink-red). Third row: *Cryptothecia* sp. (UV light blue thallus). Forth row: *Pertusaria* sp. (UV orange thallus). Photos R. Lücking.

and 400 nm, and is called so because it is just beyond the visible light recognized by the human eye as violet. Because of its high energy level, UV radiation can cause permanent damage to organic molecules and structures, including in humans.

Natural Sunscreens

The answer of nature to high UV radiation is simple and elegant: Many organisms exposed to high light intensities during the day evolved adaptations that convert UV radiation in other, less harmful forms of energy, either heat or lower energy light levels. Others just reflect excessive amounts of light. Dark pigments (usually melanins) ranging in the spectrum from brown to black convert excessive radiation to heat. This might be a useful adaptation in cold environments with high UV radiation, such as mountaintops, but in the hot jungle, it would kill the organism otherwise, by overheating and dehydration. Thus, many lichens in the jungle have opted for another solution. Instead of producing pigments visible as colors, their secondary substances have the capacity of fluorescence, which means that high energy ultraviolet light is captured by the molecule and converted to lower energy visible light, which then can be used in the photosynthetic process or simply emitted from the lichen. Each different substance converts the same UV light into visible light of different wavelengths, hence the multitude of colors when looking at different lichens. The most common substance is called lichexanthone, giving the lichens that produce it a bright yellow fluorescence. Other xanthones fluoresce in the orange spectrum. Blue fluorescent lichens are usually caused by alectoronic acid or similar compounds. Yet, the sources of other color effects are largely unknown, and open opportunities for scientific study. Under normal light conditions, these effects are not visible, because the fluorescence disappears as background signal behind the overall light spectrum, which makes the lichens look white. During the night, however, and using an ultraviolet light source that emits light at a specific wavelength of 365 nm, just beyond the wavelengths visible to the human eye, the story is different. Not just different, spectacular. Mindblowing. Literally "aaah"-some. Even a little addictive.

The Enchanted Jungle: A Nightly Lichen Tour

The potential of this spectacular show to generate interest in tropical lichens has been put into action in Costa Rica, at the renowned Las Cruces Biological Station and Botanic Garden. Las Cruces is one of three permanent Costa Rican field stations run by the Organization for Tropical

Studies (OTS), a non-profit consortium of over 60 universities based in the United States, Latin America, South Africa, and Australia. These stations are hosts to a wealth of tropical biology courses organized by OTS on an annual basis. In 2007, Robert Lücking organized the first tropical lichen specialty course as part of the OTS program at Las Cruces, and it was the second course held in 2012 that inspired the idea of designing a tropical lichen tour at the station, using the colorful lichens glowing in the dark to attract people's interest to lichens. Robert, Professor James Lawrey from George Mason University in Virginia, PhD student Manuela Dal Forno from Brazil, Colombian-based lichenologist Bibiana Moncada, and Costa Rican resident lichenologist José Luis Chaves spent several days in designing a self-guided, mapped tour through the grounds of the station that explain all the basics about tropical lichens, their biology, importance, and potential uses. At

Figure 5. The group of researchers at Las Cruces Biological Station, Costa Rica, designing the "Enchanted Jungle" night lichen tour. Photos R. Lücking.

the heart of the tour, or the teaser, so to say, is the nighttime event. Using appropriate safety measures, the tour looks at trees covered with white lichens, first using a normal flashlight and then, after some explaining that increases the tension, the portable UV light is turned on, and there they are again, the "aaaahs" and "oooohs" and "wooooows." The effect is usually disbelief. Or that some magic must be involved. Or at least a trick by the tour guide. But then realization settles in, realization that tropical lichens are much more than boring white spots on tree bark. Lichens are cool, definitely.

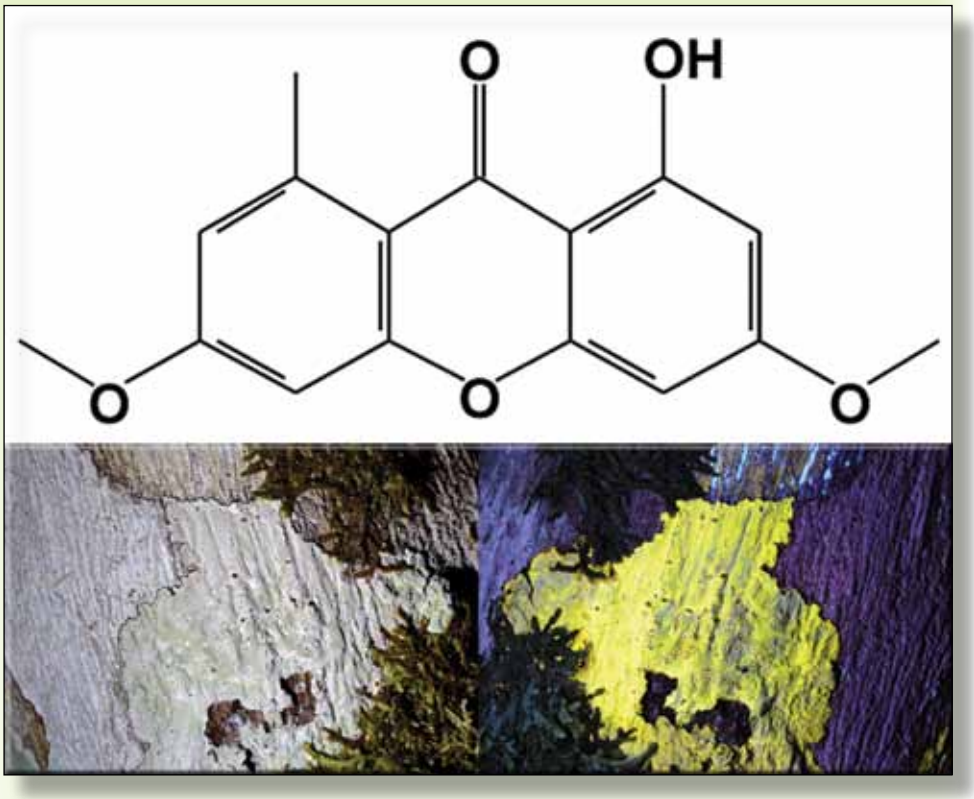

Figure 4. Lichexanthone is the most common lichen "sunscreen." It "glows" bright yellow under long-wave UV light (here shown with the lichen *Diorygma epiglaucum*). This is caused by the two "aromatic" rings of the molecule, formed by unsaturated double bonds. These bonds absorb long-wave UV radiation and transform it into visible light at lower energy, thus avoiding damage to the lichen harmful UV radiation. Graphic and photos R. Lücking.