Nectandra Institute

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Of Mosses & Liverworts

On my quiet walks through the cloud forest, I feel compelled to reach out frequently and touch the beautiful green fur that is coating everything in sight – the leaves, the trees (dead or alive), the soil, the rocks, or just hanging freely as large soft masses in mid-air. Covered with delicate water droplets, nature's shimmering and finely textured coat is mesmerizingly beautiful. My sensorium equates the cool velvet with other-wordliness while my mind announces mosses and liverworts, two of three members of a plant group known as bryophytes. They have become my favorite study subjects in the last few years. Not just for their ethereal appearance, but also for their ecologic importance for the planet and not just the tropics.

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Several years ago, in a hurried phone conversation with our Institute president Alvaro Ugalde, I mentioned my interest in initiating a systematic inventory of mosses at Nectandra. He asked what I needed to get started. "Plane tickets and living expenses for a couple of expert collaborators" I answered. After a few seconds of deep thought, Alvaro's merely said "I have an idea" and moved on to other topics. Weeks later, he revealed that he mentioned my project to a potential donor, who summarily vetoed the request and replied that "mariposas nocturnas" have lowest priority on his list of conservation projects. After several seconds of bewilderment, wondering how my "mosses" metamorphosed into "mariposas nocturnas", I asked Alvaro if I heard him correctly. He emphatically nodded and repeated that I had wished for a project on moths, *i.e.* "mariposas de noche' in Spanish, right?" at which point we both burst out laughing. Alvaro's moths eventually were given a second chance and remorphed as mosses, which very fortunately were high on the donor's priority list.

I remember being shocked that there are about 4000 species of bryophytes in Central American tropics alone, with another estimated 20,000 distributed on every continent, including the polar regions. Furthermore, our state of knowledge on bryophytes is decades behind other fields of biology. With climate change, the urgency to get basic field information and specimens is paramount. Once again, I find myself with an opportunity and in a position that requires action.

As it turned out, the bryophyte project encompasses more than mosses. It included liverworts and hornworts, collectively known as bryophytes. As I learned more about them, I have come to appreciate their nursing roles among living things and to realize their vital place in regulating earth's climate. In a more philosophical vein, they channeled my musing into the meanings of "evolutionary fitness".

First of all, biological fitness necessarily involves efficient reproduction. How do the bryophytes do it? They share fundamental features of their life cycle but differ greatly in the details. Just as vascular plants, they do it in biphasic cycles, alternating between sexual and asexual phases. In vascular plants, the asexual phase is dominant and persistent while the sexual stage (flowering and fruiting) is brief, short, and dependent on the continuing presence of pollinators in the majority of cases. In contrast, the actual bryophyte plants are the (haploid) sexual stages. Fertilization of the gametes requires water for the motile sperm to swim short distance to find the stationary eggs. Within days, embryos develop inside protective capsules known as spores which are released or expelled, then washed by water or propelled by wind to their next landing spot. Hardy moss spores have been known to travel long distance across continents carried by the trade winds. The efficient life cycle of bryophytes, in short, is what permits rapid colonization and increase in size of the population, thereby enhancing species distribution.

If evolutionary fitness encompasses lineage longevity, the bryophytes certainly meet the requirement. The consensus among molecular phylogeneticists is that bryophytes are descendants of three very old, but separate plant lineages. Bryophytes predate all plants except for the mostly aquatic green algae, and have been around for some 450 million years.

I have now spent many happy hours staring into the dissecting microscope, awestruck by the beauty of the delicate arrangements of leaves, stems and the unending diversity among them. If I had several lifetimes, they would not be enough to appreciate the innumerable differences amongst them (see photos). In time, I was able to recruit two collaborators, James Henrich, in between jobs (previously at the San Francisco Conservatory of Flowers and now at the Los Angeles County Arboretum), and Dr. Daniel Norris of the Jepson Herbarium, University of California Berkeley. Jim helped me set up our specimens inventory and database system, which include photos and photomicrographs. We started to collect samples, which turned out to be mostly complex mixtures of multiple species all tangled together. We painstakingly teased the mixtures apart, photographed and recorded each member species. By studying the frequency of association with host plants and with each other, we hope to glean some ecologic information from this type of survey.

Jim was followed by Dan, who spent two very intense weeks collecting at Nectandra Garden. Back in his UC Berkeley lab, he has identified over half of the 800 some specimens collected. Of special interest are the 3 dozen epiphyllous (found on leaves) bryophytes of vascular plants. On one single leaf, Dan recognized a dozen species of liverworts, and his colleague/spouse was able to identify 23 lichens. Dan and Nancy's taxonomic data will serve as both reference and voucher specimens for later work-up by nuclear acid identifications.

Does small size contribute to fitness? On first glance, it doesn't seem so. The absence of lignin in bryophytes is one of the reasons for the diminutive size. Lignin, combined with cellulose, line the conducting channels (vasculature) of later land plants. It is what

gives plants structural strength and a system of water/nutrient conduits. Lacking lignin, bryophytes have neither true modern leaves, stems or roots. They depend on moisture and nutrients that can be absorbed through the surface of individual cells on the plant. As a consequence, bryophytes are not only small, they are ultra-sensitive to changes in growing conditions, and thus excellent bioindicators of environmental disturbances and contaminants.

Although hydration and turgor are controlled by the environment, bryophytes are far from helpless against the elements. Many evolved vital and specific adaptibilities not found in the vascular plants. For example, *Sphagnum* moss can absorb water with equivalent weight to 20-30 times their dry weight. Yet, many of the superabsorbant bryophytes can withstand complete desiccation, going dormant during dry spells. Independent of the length of dormancy, mosses take up water instantaneously and resume photosynthesis on contact with water. This ability to rapidly activate the biochemical processes to regulate cellular osmotic pressures during rehydration is unique among living things and is nothing short of miraculous. Decades-old herbarium specimens are known to revive and photosynthesize within hours of wetting!

Given time, small does not mean insignificant. Bryophytes' miniature size permits growth on substrates denied to most vascular plants. Tolerant of a wide range of temperatures, they are found on all the continents, anywhere that allows photosynthesis, such as rock outcrops, surfaces of soil, of plants, even of sand dunes in deserts and of ice caps at earth's poles. Peat bogs of mostly decaying *Sphagnum* in subarctic regions have been accumulating since the last glacial ice age, in immense deposits that are many meters deep. High in organic matter, peat was historically an important fuel in the northern countries. Highly flammable dried, burning peat bogs had been known to smolder for decades, even centuries! Today peat remains an important source of agricultural organic supplement. Lesser known are tropical peat bogs that can be up to 20m deep. Fire in recent years used to clear peat land in Indonesia contributed to indisputable sharp spikes of CO_2 in the atmosphere. Today, vast reserves of peat are still buried under the earth's permafrost. Global warming is expected to accelerate decay of the defrosting peat and the release of methane and CO_2, both greenhouse gases. The collective global biomass of frozen bryophytes alone is estimated to be 3 times that of vascular tropical forest. Contribution of biomass of tropical peat land is as yet unmeasured. It has become clear to environmental scientists that significant byrophytic biomass must be included in their calculation of atmospheric carbon.

"Survival of the kindest" may be just as good a dictum as fitness in the evolutionary context. Distinct from that of vascular plants, bryophytes occupy a unique niche in the water, elements and energy flow on the Earth's surface. Their tolerance to desiccation, ability to rehydrate, capacity to absorb, to retain and release large volumes of water and solutes, their extensive geographical distribution, all make them an effective and immense reservoir for water and nutrients spanning the entire globe. They maintain moisture equilibrium, they help capture and trap nutrients, provide food and habitat to largely unstudied organisms, often to the benefit of all within their spheres. As pioneer colonizers of minute surfaces, they stabilize soils, prevent erosions, deposit organic matters for present and future colonizers. In short, residual bryophytes accumulating from the past combined with those present, exert a tremendous influence on terrestrial ecosystem succession. Primitive and miniscule the bryophytes may be, insignificant they are not.

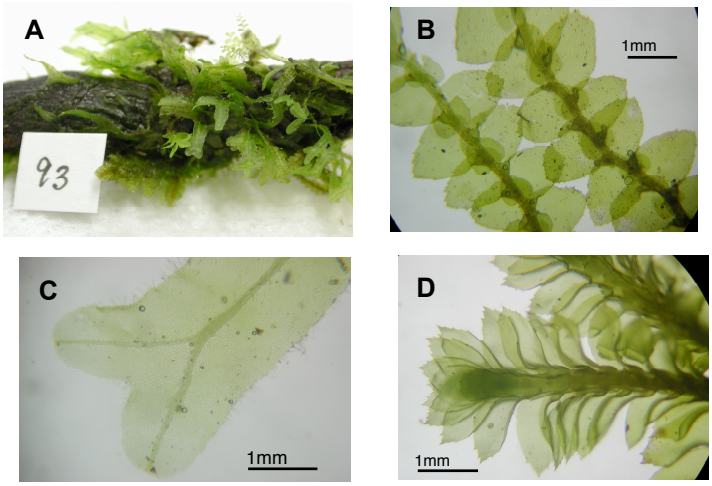
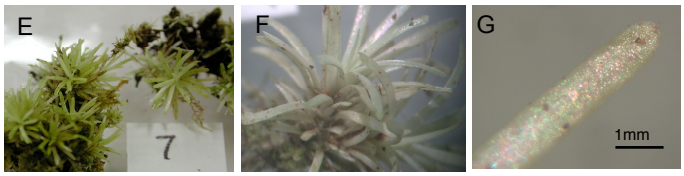


Fig A. Specimen #93 of mixed leafy liverworts growing on small branch. Figs. B–D. Representatives from at least three genera, teased from #93



Figs. E - G. Unidentified light green moss, growing on rocky substrate. Under strong light. of the microscope (F,G) and magnified, 10X and 30X respectively, the individual cells appear irridescent.

~ ~ ~ *The editor* ~ ~ ~

What gives me hope?

The following is a slightly edited reply from Luis Villa, a member of our staff, to a friend's question. He kindly agreed to share it with our readers. –Ed.

A couple of weeks ago, I went to a local elementary school to give a class of 5th graders a short presentation. As part of the presentation, they saw *Agua...más que un tubo*, which was a real treat for them because it was filmed in their local community so they recognized many of the places and faces in the video. The other part of the presentation was me talking about some of the "bigger picture" concepts that drive the environmental effort and movement towards sustainability. One of those concepts is the difference between linear, extractive processes *vs.* cyclical, renewable ones. I started by making sure they understood the term "process" and then gave them several examples of both linear and cyclical ones. I concluded my presentation by comparing planet earth to a spaceship with limited passenger capacity and resources, but with the technology to support its passengers' lives indefinitely so long as its physical limits were respected. This, in an effort to

illustrate the concept of a (almost) closed system. Prior to giving my presentation, I'd been somewhat worried that the ideas I wanted to discuss would be beyond the kids. But their enthusiastic participation showed me otherwise. Despite their young age, they were able to understand what I was trying to tell them rather easily.

A few months ago, during a water management association meeting in a local rural community, I was asked by the association's president to give a brief chat about Nectandra Institute, our work and environmentalism in general, to the residents in attendance. I had just finished reading Paul Hawken's *Ecology of Commerce* so I was inspired to talk about what I like to call "a history of the flow of the world's capital - the abridged version." I asked the various kids in the audience to help me out by coming to the front of the room in order to represent the different types of capital over time. Placing all the kids on one side, I started out in prehistoric times, before there were any humans, telling the audience that all the kids gathered on one side represented the world's *natural capital*, as yet undisturbed by human hands. Then I "fast-forwarded" to the appearance of mankind on earth, took a couple of kids from the first group, formed a second one and called it *human capital*. Then, after talking briefly about our nomadic beginnings, I landed on 10,000 B.C., the agricultural revolution, and with that a third group of kids, this time representing *manufactured capital*, was formed. We all know, of course, that the agricultural revolution was the impetus for the first major population explosion, so I took even more kids from the *natural capital* group and introduced them to the *human capital* group. To make a long story short, you might imagine what the natural capital group was reduced to when I had finished going through the industrial revolution and landed on the present day. The question I asked the audience at this point was, "Do you see something not quite right with this picture?" Like the fifth graders, they got it.

Two years ago, I was not an environmentalist, not even close. After moving to Costa Rica from the U.S., one of the first ideas I had for making a living here was housing development, since I'd had a stint as an affordable housing project manager in California. Actually, I grew up on the outskirts of Los Angeles, California. The closest I came to nature growing up was going to the city park or riding my bike in the cemented over flood channel that is the L.A. river. In college, I studied psychology, not environmental science. So it goes without saying that, like most people, I've never bothered much with concepts such as sustainability, conservation, and the biosphere's carrying capacity. Climate change, peak oil and overshoot were all but unfamiliar terms to me until relatively recently. My world view has mostly been shaped by my experience with the conventionally accepted notions, at least in the industrialized world, that bigger is better, exponential growth is good, and material accumulation is a requirement for well-being (all linear processes, by the way).

But before allowing the booming local real-estate market to draw me into building cookie cutter homes for middle income Costa Rican families, I had the incredibly good and very random fortune of finding work with Nectandra Institute. In order to improve my *eco-skill* set I started a process of self-indoctrination, involving soaking up as much as possible from my co-workers, who had much more experience in conservation work than me, but primarily by reading books by folks such as Hawken, Donella Meadows, and Jared Diamond. I began to learn about and appreciate the very real connections between forests and water, biodiversity and health, the environment and us. I started to understand that *environmental services* isn't just a catchy eco-term made up in order to market the idea of conservation to a consumerist society that is used to seeing everything else marketed, commercialized, and branded. No, *environmental services* referred to very real and tangible benefits we continuously receive from nature, benefits I'd seriously taken for granted just about all of my life. I was blown away when one day I learned that if we were to attach a price tag to all the goods and services we receive from nature each year, the amount on that price tag would be twice global GDP. I also read about the controversy surrounding such estimates, but it didn't matter to me, because my human instincts immediately told me that the only thing in doubt was just how understated they really are. Like the fifth graders and the audience at the water association meeting, I got it.

All of this is my way of saying that my hope comes from the fact that I'm just an average person who "got it". I'm like an average Joe, a "Joe the plumber" if you will, who in an epiphany slightly drawn out over the last couple years of his life, has come to understand that spreading the wealth is absolutely necessary in order to achieve environmental equilibrium and sustainability. And not just spreading it amongst human hands, but rather returning some of it, maybe lots of it, to nature, motivated by a new economic paradigm that at last reins in all of our current society's socio-environmental cost externalities and fully accounts for the value of natural capital to our lives, thus closing the flow of capital loophole. An eco-loan to a rural community in Costa Rica, on which not monetary interest, but rather *ecological* interest is charged is but a tiny manifestation of this new paradigm. It is also exemplified by the implementation of higher water rates by water management associations so they have the resources necessary to buy and protect groundwater recharge lands instead of settling for just repairing PVC water lines and concrete storage tanks. Or it is made visible by schoolchildren who, despite their young age, can answer correctly when asked "Where does water come from?" (see scene in *Agua...mas que un tubo*).

My hope comes from the fact that it has taken me a relatively short amount of time to understand this, despite having spent most of my life not getting it. It comes from the fact that all it took was a little nudge in the right direction. My hope comes from my belief that it is my human heart and instinct that has allowed me to get it. It comes from knowing that every average Joe or Jane is a human being, with a heart and with instinct. It comes from knowing that, as a natural part of the beautiful and amazing web of life, we humans are not set up to fail, we are predisposed towards success, but we must act towards achieving that success. My hope comes from me believing that everyone can and will "get it".

Luis Villa,
Nectandra Institute

Fall Events

Nov. 08 – School children from the communities of Angeles Norte and Alto Villegas each "adopted" young trees donated by Nectandra Cloud Forest Garden. Each child will give home care for his or her sapling and then plant it next year in the groundwater recharge area in the property purchased by the communities' water management association.

Nov. 08 – *Agua...Más Que un Tubo*, a short documentary film about the Balsa River watershed communities' efforts to protect and reforest critical groundwater recharge areas, was shown at a forum on water-related issues held at the University of Costa Rica, San Ramon Campus. The film was co-produced by Nectandra Institute and CAVU, a U.S. non-profit organization dedicated to educating and engaging stakeholders about natural resource management . The film can be viewed here in two parts on www.Youtube.com under its title *Agua...mas que un tubo*

Nov. 08 – The property purchased by the water management association of Angeles Norte/Alto Villegas with an eco-loan from Nectandra Institute was formally approved for payments for environmental services (PES) from Costa Rica's National Forestry Financing Fund (FONAFIFO). PES disbursements are contingent on meeting minimum environmental restoration standards and will provide the owners with additional reforestation funds.

April to Dec. 08 – School children and docents, in groups of 30-50, from the all the primary schools from four communities visited the Nectandra Cloud Forest Garden to learn about the forest, its biodiversity, its influence on water and importance to their own lives. All four communities are a recipients of an eco-loan from Nectandra Institute.

Dec. 08 – VIDA Club Palmira completes its water awareness and environmental education program to local 6th graders with a visit to Nectandra Cloud Forest Garden. Between July to December, 2008, club members organized and presented workshops every two weeks for the schoolchildren titled *Caring for our Community's Water*, covering topics on as water, biodiversity, reforestation, pollution and contamination.

Dec. 08 – Intern **Jason Lattier**, a graduate of Longwood Gardens Horticultural Programs, started plant meristem *in vitro* cultures for Nectandra Garden's Plant Reproduction Program. His goal is to be able to clone plants that are difficult to propagate or have no seeds. The meristems cultures will complement the orchid embryo cultures program initiated by James Henrich previously.

Dec. 08 - Our president **Alvaro Ugalde** was selected as a Fellow of ASHOKA, a non-profit international organization that awards 3-year stipends to outstanding leading conservationists who are making social impacts around the world. For details, please visit their website ASHOKA.org.