Explore San Diego Bay with these informative and transforming books created by the students of The Gary and Jerri-Ann Jacobs High Tech High:

-The Two Sides of the Boat Channel: A Field Guide [1]

-Perspectives of San Diego Bay: A Field Guide [2]

-San Diego Bay: A Story of Exploration and Exploitation [3]

-San Diego Bay: A Call for Conservation [3]

[1] High Tech High
[2] Next Generation Press
[3] California Sea Grant Program

BIOMIMICRY

Respecting Nature through Design

by the students of
THE GARY AND JERRI-ANN JACOBS HIGH TECH HIGH

Designed and Edited by
Natalie Stephen
Brittney & Christopher

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FOREWORD

Two summers ago I was standing with Dr. V., High Tech High biology teacher Jay Vavra, facing an abrupt, sheer wall of island rain forest. The "island" was the heights of Mount Gorongosa, the giant oval, granite massif rising from the midlands of Gorongosa National Park in Mozambique. We were preparing lessons for the new digital textbook we've been working on since 2009. It was a very good day for me. It was my first rain forest, my second helicopter ride, and the latest of many work sessions with Jay, who guzzles more fun from science and delivers more fun than anyone I've known.

I was actually a little daunted at that moment. The face of this rain forest is a very sharply defined ecological boundary. It has a tightly woven skin of roughage and forest shag, as if the forest was draped with a heavy ocean fishing net. How do you get in?

You cut a door. For true. You cut a door-shaped door in the skin and you clamber on in. It's fun in there. You gotta try it.

Then Jay went to work collecting. What he collects in the baggies and notepads he pulls out of the twenty pockets in his clambering clothes are stories, which he brings back to his students. This isn't a note about Jay. It's about his students, who are our students, and what we should do with them. Jay and the other practitioners of problem-based learning think we should teach students, and then make them teach us.

For a long time, biology was taught from atoms to molecules to metabolism to cells to organs to organisms to ecosystems. That works OK. But it's just as valid and sometimes more interesting to shuffle the chapters and start anywhere. Biology is like that. You can cut a door-shaped door anywhere and clamber in. Focusing on biomimicry is a way of studying biology as a whole. Focus on the exotic weaponry, jutting from jaws and appendages that critters use to keep each other in line. (Students like that stuff. Me too.) Study the devices that the forest uses to store water until it's needed. Study the structures that plants use to collect energy from the sun. Put together everything that you know with everything new that you learn, keep doing that, and pretty soon you're fully appreciating nature's design.

Jay and his teaching partners at High Tech High up the ante by integrating social issues and math in their biological explorations. They open two new doors into the forest for their students. You understand the forest much better if you can see it from different perspectives. You know the forest much better if you can measure things within it. You also develop an appreciation for the forest by realizing what the rain forest gives to humans. Unfortunately, the bigger story is often what humans take. Humans have taken over 50% of the Mount Gorongosa rainforest in the last 6 years.

This book of biomimicry teaches us that we can "take" lessons from nature without disturbing nature. We might cut a small door occasionally to look around, but after exiting with a notebook full of ideas and a head full of designs, the forest is still full and thriving.

High Tech High students have made several big expeditions in their own backyard jungle in the last few years. They documented the San Diego Bay in several rich, award-winning publications. Note: They documented, which is hardcore scientific work. And they published, which is also hardcore scientific work. I'm a science publisher and I thrill to the publications these students have done. Something strange happened between my first textbook 25 years ago and my most recent one. Professional production tools became composition tools. Writers became compositors. Colored pencils became

ABOVE: BRITTNEY INSTRUCTS East African conservation partners during the Bushmeat Identification Workshop at Mweka College in Tanzania -- a wildlife forensics course run by Dr. Vavra and his students.

BELOW: TYLER AND OTHER High Tech High students learned about aspects of sustainable hunting and gathering while living with the Hadza tribe of the Yaida Valley, Tanzania.

Photoshop. These students have been raised with the tools of professional communicators in their classrooms, and they have clearly mastered them.

The High Tech High students make books, grand, high-production, worthy scientific productions. I marvel at the execution and seriousness of these students. They're showing us what we can expect from students if we teach them well. They'll teach us. I learned a ton from their latest excursion, *Biomimicry: Respecting Nature Through Design*. You will too.

Jay has taken several caravans of students to East Africa on study trips. The point is not to go to Africa to see the unique stuff that is only there. The point is to come home, newly ignited to see the strange stuff at home with eyes that see. This book by the High Tech High students isn't just a field guide from the latest expedition. It's a book about life in the round, and about how a modern explorer sees it and sketches it. It starts by integrating the subjects of biology, math, and humanities. And it ends by artfully telling us how we need to live in order to sustain life on earth.

These students have high standards. They went through all the right motions—they wrote, drew, photographed, designed, edited, proofed, trafficked media assets, and went through draft after draft. They're publishing scientists, with a lot to teach us.

Way to go, kids.

Morgan Ryan
Project Director
E.O. Wilson's Life on Earth - Digital Biology Textbook

JANINE BENYUS
MOTHER OF BIOMIMICRY

After hearing Janine Benyus, distinguished author and voice of biomimicry, speak to thousands in a packed theater at the 19th annual Bioneers conference in San Rafael, we had the unique opportunity to speak with her about her work and vision for the future of this blooming approach to design inspired by nature. Sitting on a lush, green knoll next to a tranquil pond, we discussed Janine's vision as the beauty which inspires her work surrounded us.

Student Interviewer: So first off, just for perspective, what exactly do you do?

Janine Benyus: I try as best I can to increase people's respect for the natural world. That's number one. Seriously, that's mission number one for us at our company. I think of myself as a natural history writer. That is how I began, and wrote five books in natural history about plant and animal adaptations. Then I wrote Biomimicry. I basically chronicled the people who were actually looking at those plant and animal adaptations and trying to mimic them.

Then an interesting thing happened. I was sitting there about to write another book, my seventh. I was deep into research when the phone started ringing. It was various companies, and they were asking, "Could you tell us how life works? We're making a membrane to take salt out of water. Could you tell us how the nasal glands of seabirds work, how mangroves work, how all the fish in the salty sea manage to live on freshwater? They have to remove salt from that water, right?" The ocean is full of filters. From warm water corals to penguins – they're all good desalinators. Your kidneys are great desalinators too.

I started to realize that what these companies were suggesting – send over some biologists to inspire our inventors -- was a whole new career. We now call it Biologists at the Design Table. BADT. B-A-D-T. We even have batmobiles (smile)... But at that point there was only one of me. Luckily, a young woman named Dayna Baumeister, who was earning a PhD at the University of Montana, had recently called me. She had read the book and told me she shook for three days. She said, "I am so excited; this is what I want to do." I asked, "What do you mean this is what you want to do? Why don't you come to my house and we'll brainstorm a little."

That was in 1998, and we wound up starting this company called the Biomimicry Guild. Now there are ten of us; consulting biologists who work with designers, engineers, and architects - anybody who is inventing something. We present them with natural models which inspire them to

HIGH TECH HIGH STUDENTS interviewed Janine Benyus at the 2008 Bioneers Conference.

design differently. In 2006, we started the Biomimicry Institute, a non-profit dedicated to educating the next generation of biomimics.

SI: So would you say that's the goal of the Biomimicry Guild and Biomimicry Institute, to inspire people to design differently in accordance with nature?

Benyus: Absolutely. Not only in accordance with nature; the goal is to increase respect for the natural world. That's number one. Then we're hoping that people will design differently. Not only in accord with nature, but actually emulating nature. The goal is that our technologies would be functionally indistinguishable from those in the natural world. Imagine seeing San Diego from the sky, the skyline and the buildings. Then imagine seeing the Amazon rainforest from the sky. Those two pictures right next to each other. Now, I don't think the city is going to look like the rainforest, but our goal is that the city and all the technologies within it will function like that rainforest. Our habitat will be functionally indistinguishable from a natural system. That's what we're attempting to head towards. We are nature. We're a biological species, and what we're striving to be is a welcome species. In the big picture, that's our goal. To fit in here, on our one and only home.

SI: Do you think that the distance that separates humans from nature, from our roots, has created the need to practice and publicize biomimicry?

Benyus: That's a really good question. That's a question that has an answer within it. Because the question is, why haven't we done this before? I think the answer is within your question. I think there's this large distance between humans and the rest of the natural world. And there are several reasons for that. One is the long-standing mind/body split in our culture. You could go all the way back to Descartes; back to the belief that there are humans and then there's the rest of the natural world. It has actually been quite a cultural campaign, whether it's been conducted through philosophy or religion, to separate us from the "lower animals." That campaign worked very, very well, and we now honestly do not believe that we're part of nature. At this point, we believe that we're worse than nature, that we don't belong here, and that's really a shame. I think there's been this split, and splitting nature off from us allows us to do a lot of things that we're not proud of. It allows us to treat the natural world with very little respect, right? Because it's not us. There's us and there's "other."

It's really at the crux of a lot of behavior. In the same way that we, culturally, think of other races as "other," as not like us, not quite as good—that's how we think of nature. And that belief allows us to do things that we're not proud of. Separation is what's allowed us to get to this environmental emergency; it's also made us incredibly lonely, right? So biomimicry is an attempt to heal that separation, to remind us that we're not all that different from the rest of the organisms on the planet - that when it comes right down to it, we're all just trying to meet our needs, put our kids to bed at night, build our houses,

power ourselves, and feed ourselves. Really, what's the big difference? When you get down to that level, that's when mimicking other organisms begins to make sense. You say okay, there's a tree, meeting its needs without being able to move to get supplies. How is it meeting its needs for energy, nutrients, or safety differently than we do, say, in a building?

Once you take away that false separation between us and the natural world, you can see that this tree is moving water and nutrients a hundred feet up without a pump; it's gathering solar energy; it's cleaning water; it's growing stronger in response to wind. It has to keep itself safe in storms, safe from fires, even earthquakes. It's got to do a lot of the same things that our buildings have to do. So once you remove that false separation, all of a sudden you can model your technologies on that tree's technology.

SI: So if the ultimate goal is getting back with nature, when do you see us getting there?

Benyus: When? I think we're already there in bits and pieces. A friend of mine is an architect. She does a lot of public speaking, and for years she's been asking audiences of architects to close their eyes and imagine where they're happiest; where they're most comforted; where they feel most creative, most at home, most like themselves. And then she'll ask, "Now who is thinking of someplace outside?" Nine out of ten hands go up. And these people are architects! They design buildings for a living, but that's not where even they are happiest.

I think we naturally gravitate towards the natural world. I think we have, as E.O. Wilson calls it, "biophilia." Look how much we love our pets; collectively we spend billions each year to live with animals in our houses. I mean, it's not that people don't love nature; we do! But we compartmentalize. "Okay, I'm at work now, that's something different. Caring about my kids, my tenderness, my feelings about the natural world, I'm keeping those at bay now."

I don't think we have to go as far as you think we have to go. Do you know what I mean? I think it's a matter of reconnecting with something that, evolutionarily, 99.9% of the time we've been on Earth we were right in the middle of. We were hunters and gatherers. We saw no separation. So the separation is relatively recent if you think in evolutionary time. People are homesick for the natural world. You reconnect them with the natural world and what happens? Their hearts melt. The question is, can we get the hundreds of thousands of people who have the responsibility for designing our world back in touch with the natural world? That would be a start, right? Then, if our designs become functionally indistinguishable from nature, could we come to a point at which there's more of a permeable boundary between the two? Between our technologies and nature's technologies?

SI: Right now, what can everybody be doing to help get back there?

Benyus: Go outside. Go outside! Grab a doorknob and twist. I gave a talk one time, and I made a joke about getting outside; I said you can find all the answers you need at "www.gooutside.com." There were twenty people in line afterwards asking me, "What's that website?" It's called a doorknob. It's called open the window and climb out of it. It really is as simple as that. That's the first step. The first step is to go outside and see with new eyes.

SI: So it seems you have a lot of hope for biomimicry in terms of societal woes, but what about solving the most pressing environmental issues like climate change and getting clean water? How can biomimicry be applied there?

Benyus: Climate change. Let's look at gathering energy. Photosynthesis is a model for new thin-film solar cells called dye-sensitized solar cells. To make those solar cells more efficient, innovators are using photonic crystals which are mimicked from butterflies. On the top of the solar cell, they're putting a thin film, based on the moth eye. The moth has a completely anti-reflective surface because it doesn't want its eye to shine at night when predators are coming around. It has little pillars on its eye to drink the light in, but not let it out. So you've got a solar cell based on a leaf, capped by a moth, with a butterfly idea underneath—a chimera for gathering solar energy.

What about storing that energy in the form of, say, hydrogen for fuel cells? Leaves split water all the time. That's a good source of hydrogen ions. People are mimicking the water splitting compound in leaves. There are about four or five labs crazily moving towards commercialization of that. I can't wait for them to get there. Wave energy? Biopower has a kelp-inspired wave-energy harvester. Wind turbines? Whalepower is mimicking the drag-reducing scalloped flippers of the humpback whale. There's harvesting the energy; there's storing the energy in the form of hydrogen, there's going all the way from sunlight and combining the electrons with CO_2 to make a chemical compound--fuel. That's what these trees do. They take sunlight and turn it into ATP, sugar, starches, cellulose. That's how they store the sun's energy.

There's also bioinspired work going on in with fuel cells. A fuel cell breathes in its raw materials—oxygen and hydrogen—and it creates electrons and water as a byproduct. So there's oxygen chemistry going on and we're learning from aerobic bacteria about that. We're learning about the hydrogen part of the chemistry from cyanobacteria. They have a particular hydrogenase enzyme that we're trying to mimic to get those two parts of the fuel cell working well. The gases flow through what's called bipolar plates, and a company called Morgan Fuel Cell is making those plates using the shape of the branches that you see in your lungs. So in a fuel cell, you've got the most ancient bacteria, the cyanobacteria. You've also got aerobic bacteria, which are like those in our cells, and you've got lungs. Another chimera.

On the energy-saving side you've got all kinds of innovations. You've got energy savings in buildings, for instance. Biofuel innovators are also learning from nature. There's a scientist named David Tilman at the University of Minnesota who has looked at prairies and asked, "Okay, what if we were to take the prairie as a model for a new way of growing biofuels?" He found that a biodiverse prairie, with hundreds of species, has 238% more BTUs than a monoculture production. Plus, because the plants are perennial, you don't dig up the soil and have all those issues with soil erosion. Then say you want to use agricultural residues for biofuels - cellulosic biofuels they call

UNDERSTANDING HOW GIANT KELP MOVES with the rhythms of the waves is being translated into new ways to generate electricity from renewable sources in the ocean.

it now. Corn stalks, rice hulls, maybe pulp waste. Unfortunately, there's a problem with it. Chemically, it's very difficult to break down cellulose. But there are other organisms that do this very well - termites. So the director of Lawrence Berkeley Labs, Steven Chu, Nobel laureate, says termite guts will save the world. His team is looking at the chemistry of bacterial symbionts that live in the gut of the termite. How are they breaking down that cellulose? Nature's ideas can contribute just about anywhere you look in the climate change equation.

Then the big one: How do you get excess CO_2 out of the atmosphere? This is serious stuff. What if we took CO_2 and used it as a feedstock for plastic, fine chemicals, or building materials instead of pumping it underground? If we were more like inventive organisms - and we're getting this way - we'd say, "Wow, lots of CO_2. Good, now let's figure out how to use it." We are starting

to say just that, at companies like Calera (CO_2 to cement) and Novomer (CO_2 to biodegradable plastics).

So you've got gathering solar energy, storing it, converting it to biofuels, and fixing CO_2 instead of burying it. But even these great ideas won't help us with the ultimate question: How do we curb our consumer appetite? Biomimicry is not good for everything. We still need ethics and morals and meditation and hugs to fill the space inside our selves and grow out of our adolescence; technology can go just so far. There's quite a bit of promise in it, but we have to work on saying "enough" too.

SI: Do you have any Biomimetic solutions to address our project on San Diego Bay?

Benyus: Oh my gosh, yeah! It's water quality, right? Nature has incredible low-energy filtration strategies, and ecosystems like marshes can be mimicked to clean water (see Floating Islands International). Another promising technology is mimicking how microbes chelate, or scavenge very specific metal ions from water microbes are really good at saying, "I'll just take iron, or I'll just take mercury, or I'll just take gold." They need small amounts of metal for their own metabolism. They use chelating molecules called siderophores, and these have been mimicked. The idea is to tether them to thin film and then basically let them pull a specific metal out of water. Different sheets of siderophores capture different metals and recoverable amounts of metal can be removed from these sheets. It's a mining operation in a box that you sit in the polluted water. There are plenty of great ideas, and it's been great to share them with you. Check out www.biomimicry.net if you want to stay tuned to this fascinating field.

OPPOSITE: ENSURING THAT KIDS explore and get outside is one simple strategy that can help them develop a strong connection with nature.