ARTÍCULOS ESPECIALES

A letter from the United States: The fox in our backyard - Science, Serendipity and Surprise

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*The story of how Charles Darwin composed *The Origin of Species*, published in November of 1859, has been told many times during the bicentennial of Darwin's birth and the sesquicentennial of the publication of the book. It is a history well known to biologists and historians of science. The heated debate that accompanied the demonstration of natural selection as a mechanism of speciation and continues to the present is surprising. Human beings do not welcome surprise: "the emotion aroused by something unexpected." The history of science and human intellect, however, illustrate the creative stimulus of surprise and serendipity in the development of human knowledge and the evolution of culture. The lives of *Homo sapiens* would not change if our intellect was unable or unwilling to respond to the unexpected and to make connections between surprising and commonplace events. The rich diversity of South American life was surprising to the European travelers of the 18th and 19th centuries: surprising by its beauty and profusion, but also by its similarities to the creatures of Europe and Africa. Darwin's curiosity sought and welcomed surprise (Rev Méd Chile 2009; 137: 1502-7). (Key words: Adaptation, biological; Evolution; History, modern; Natural history)*

Un mensaje desde Norteamérica: El zorro en nuestro patio trasero - Ciencia, "Serendipia" y Sorpresa

*La historia sobre cómo escribió Charles Darwin "El origen de las especies", publicado en noviembre de 1859, ha sido relatada muchas veces durante el bicentenario del nacimiento de Darwin y el sesquicentenario de la publicación del libro. Es una historia bien conocida por los biólogos y los historiadores de la ciencia. La demostración de la selección natural como mecanismo de formación de las especies generó un acalorado debate que continúa hasta el presente. Los seres humanos no acogemos con simpatía la sorpresa, concebida como "la emoción despertada por algo inesperado". La historia de las ciencias y del intelecto humano, sin embargo, ilustran el estímulo creativo de la sorpresa y la "serendipia" en el desarrollo del conocimiento y la evolución de la cultura. La vida del *Homo sapiens* no cambiaría si nuestro intelecto fuera incapaz o adverso para responder ante lo inesperado y de hacer conexiones entre los eventos sorprendentes y los rutinarios. La rica diversidad de formas de vida en Sudamérica fue sorprendente para los viajeros europeos de los siglos XVIII y XIX: sorprendente por su belleza y profusión, pero también por sus similitudes con las creaturas de Europa y África. La curiosidad de Darwin buscó y dio su bienvenida a la sorpresa.*

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Este manuscrito, preparado por un Miembro del *International Advisory Committee*, se publica en el mes de noviembre, cuando se conmemora el sesquicentenario de la publicación de "El origen de las especies" y es un homenaje de la *Revista Médica de Chile* a Charles Darwin, autor de dicha obra.

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One bright, sunny June morning in 2009, a red fox rummaged about the backyard bird feeders, snuffling the scattered sunflower seeds and shells, poking his nose into depressions dug by industrious chipmunks and squirrels. This was not a sickly, scrawny animal but a luxuriantly furry and tailed, handsome red fox. It appeared to be chewing, despite the absence of any birds or rodent carcasses, which left only the bird seed as something to be eaten. My expectation was that foxes were carnivorous. Moreover, it was back again, several times, over the next fortnight.

Closer inspection of the ground about the feeders and observation with binoculars confirmed the fox's appetite for the bird seed, mostly black oil sunflower seeds, with a few tidbits of peanuts and cracked corn. Memories of our dogs eating canine "chow" made from plant sources and some questions to the veterinarian at the Buffalo Zoo confirmed that canine and feline species do indeed eat other foods than meat. My surprise at finding a fox in our backyard was perhaps amplified by the expectation that foxes would not dare to come so close to the house, that somehow a wild canine would avoid human haunts. As I think about the event, the more likely it is that I was surprised. As a result I have enjoyed ruminating about surprise in the practice of natural history, clinical medicine, and basic science.

The Oxford English Dictionary includes the following phrase in its several definitions of the word surprise: "The emotion aroused by something unexpected". Surprise implies emotions and arousal, conditions thought to be inimical to rational behavior and sound science. Indeed, to express surprise and to betray emotion are meant to be suppressed in clinical as well as scientific medicine. To be surprised, to act surprised, is considered beneath the dignity and professionalism of science and medicine. Yet in my reading of the history of medicine and biology nothing could be more productive and more professional than abiding respect for and welcoming of surprise, the arousing of emotions.

I began writing this a month after the fox's visits, on board the Yacht Daphne, moored for the day in the harbor of Puerto Ayora, Santa Cruz Island, in the surprising Galapagos Archipelago. The Galapagos Islands are one of the mythic sites of surprise, an ecologic wonderland which has

entertained, startled, and surprised curious human beings ever since they first became known to our species 600 or more years ago. The Galapagos entered the history of science 150 years ago with the publication of *The Origin of Species* by Charles Darwin and shortly thereafter entered the mythology of scientific discovery, a mythology that has intensified in this year's bicentennial of Darwin's birth and the sesquicentennial of the publication of *The Origin of Species*.

Science, the best science, is a curious amalgam of routine, careful, dogged observations and experimentation, serendipity, and surprise. Anomalous events, experiments that don't work, mistakes that do work, and the curiosity to question how they came to happen are easily passed off as good luck, but in fact good science is the product of being prepared to be surprised. There is no doubt that Darwin was prepared to be surprised when he reached the Galapagos. He had spent the preceding three years cruising the south Atlantic and coastal Brazil, Argentina, and Tierra del Fuego with the Beagle and riding horseback across the Pampas, into the Andes and the volcanoes of Chile collecting fossils and specimens of animals and birds and plants, observing and writing a copious journal and correspondence. His pre-Beagle experience had given him a foundation of natural history and geologic knowledge and the clear expectation that the science of his time was changing. Darwin during the 1830s was an unfinished naturalist, a beginner hungry for experience, curious about the world around him, and scrupulous about small and seemingly commonplace creatures, landscapes, and processes. His curiosity and appetite for surprise during the voyages and his overland treks had been whetted by finding the fossils of very large creatures and unique living birds, animals, plants, and insects in the immense landscapes of the rainforest, Patagonia, the volcanoes of the Andes, and the Pacific coast of South America.

Indicative of Darwin's curiosity and willingness to experiment is the paragraph in his *Journal of Researches* describing his encounter with the "benchuca" (Darwin's spelling of the Spanish "vinchuca"), the reduviid bug or "beetle," of the Pampas during his ride across the Andes.

At night I experienced an attack (for it deserves no less a name) of the benchuca (a species of

Reduvius) the great black bug of the Pampas. It is most disgusting to feel soft wingless insects, about an inch long, crawling over one's body. Before sucking they are quite thin, but afterwards become round and bloated with blood, and in this state they are easily crushed. They are also found in the northern parts of Chile and in Peru. One which I caught at Iquique was very empty. When placed on the table, and though surrounded by people, if a finger was presented, the bold insect would immediately draw its sucker, make a charge, and if allowed, draw blood. No pain was caused by the wound. It was curious to watch its body during the act of sucking, as it changed in less than ten minutes, from being as flat as a wafer to a globular form. This one feast, for which the benchuca was indebted to one of the officers, kept it fat during four whole months; but after the first fortnight, the insect was quite ready to have another suck¹.

Although he does not state who all of the experimental subjects were, except that one was an officer, it is likely that he himself was bitten². There is no mention of a captive guinea pig or chicken and it was likely that he was bitten more than once and by more than one "benchuca" since he kept the bugs for at least four months³. He seems to have been fearless with bugs and beetles considering his autobiographical account of finding three novel or rare beetles on one occasion which, in order to bring all three back to his collecting equipment, he put one into his mouth.

But no pursuit at Cambridge was followed with nearly so much eagerness or gave me so much pleasure as collecting beetles. It was the mere passion for collecting, for I did not dissect them and rarely compared their external characters with published descriptions, but got them named anyhow. I will give a proof of my zeal: one day, on tearing off some old bark, I saw two rare beetles and seized one in each hand; then I saw a third and new kind, which I could not bear to lose, so that I popped the one which I held in my right hand into my mouth. Alas it ejected some intensely acrid fluid, which burnt my tongue so that I was forced to spit the beetle out, which was lost, as well as the third one⁴.

Reduviid bugs or vinchucas are vectors of the bloodborne, tissue dwelling parasite *Trypanosoma cruzi*, that causes Chagas disease. The clinical description and etiology of the disease were not established until 1909, more than 70 years after Darwin began to manifest symptoms that could have been caused by chronic *T. cruzi* infection⁵. It was the Brazilian scientist Carlos Chagas who discovered the trypanosome and afterwards demonstrated that it was the agent of the chronic disease we now call Chagas disease. He generously named the agent after his teacher and mentor, Dr. Oswaldo Cruz, as a tribute⁵. At the present time, about 17 million people throughout the world are infected and 50,000 die yearly due to complications of this disease. These epidemiologic facts and its clinical consequences are being progressively reversed through programs enforced by the World Health Organization and the nationals of South America.

I suspect that the sequences of the Beagle voyage and his landside excursions were beneficial to his appreciation of the microcosms of the individual Galapagos Islands. The enormous scale of Patagonia, rainforest, and Andes mountains made regional detail indistinct. In fact Darwin did not appreciate the differences in the two Rhea species of Patagonia until he was eating one of the smaller of the two Rheas, the one ultimately named for him. Perhaps the sudden recognition was the product of his experience with exotic cuisine when he was a member of the "Glutton Club" as an undergraduate at Cambridge. His continental collecting and observations prepared him for the realities of volcanoes, earthquake, and geologic events that transform landscape and set in motion the progression of biologic reclamation and restoration. Variations in altitude, rainfall, and temperature were easily observed in large scale but distinct boundaries were not easily identified except in the remarkable islands of the Galapagos. The *Journal of Researches* is laden with his observations and wonderment but the experimental possibilities of the "species problem" awaited the Galapagos experience.

The compact diversity of the Galapagos Islands, their recent origin and traceable geological history, were an ecologic microscope allowing Darwin the luxury of noticing differences among the islands and the island inhabitants. He did not

grasp all of the rich diversity. He noted the differences among the mockingbirds, but not among the finches. He was aware that the giant tortoises could be assigned to particular islands by the shape of the carapace. He observed the differences in geomorphology, volcanism, and rainfall among the islands, even those he did not set foot upon⁶. After digesting Charles Lyell's *Principles of Geology* and Alexander von Humboldt's narrative of his travels in South America as part of his reading during his travels before arriving in the Galapagos, Darwin was prepared to be surprised by the natural laboratory of the Galapagos and to return home with the lessons of the islands in mind, prepared to put them to work.

He assigned his avian specimens to John Gould and the mammalian and fossil specimens to Richard Owen, both established scientists and taxonomists. Richard Owen, who became the director of the Museum of Natural History in London, never accepted the dismissal of created species and became one of Darwin's most vocal and effective critics. The ornithologist Gould noted the variations in beak sizes among the finches but the island origin of each required additional rummaging through records of acquisition and transport and a loan of finch specimens collected by Captain Fitzroy since Darwin had not recorded in his journal notes the islands from which the individual finch specimens had derived⁷. The plant specimens, properly labeled and identified as to the source, were given to Joseph Dalton Hooker, the son of the director of Kew Gardens, a physician, and a rising botanist in British science.

The importance of plants in Darwin's formulation of natural selection as an agent of biologic change is part of the lifelong friendship between Darwin and Hooker⁸. Hooker, like Gould, convinced Darwin that the birds and plants of the Galapagos were unique. Further he could establish relationships with mainland birds and plants; relationships that implied common ancestry. When the time arrived for Darwin to write the outline of his theory of natural selection, he used the Galapagos plant and mockingbird examples and only obliquely mentioned the finches.

Upon his return to England, Darwin continued to be surprised by the information contained in his collection of specimens. He was not yet

committed to or confident of the nascent concepts of adaptation and natural selection. I suspect he simply enjoyed the excitement of finding new items that helped to construct a plausible and testable hypothesis. As many scholars have written, he was consumed with anxiety about the implications of his ideas and the controversy they would foment. So he continued to collect specimens, perform experiments, and assemble data from a worldwide group of correspondents that added, bit by bit, to the documentation of adaptation to environmental events and the selection of favorable adaptations.

After the family moved to Downe, Darwin established his gardens, his worm observatory plot, and a greenhouse; all in their own way islands as sharply bounded as the Galapagos Islands. The significance of the web of connections among plants, bird and insect pollinators, climate, and isolation on the Galapagos Archipelago needed the detailed examination of his collected specimens to shape the questions about speciation⁹. The islands, like a greenhouse or dovecot, were natural examples of enclosed collections of diverse living things where adaptation and selection could be observed. Darwin never returned to the Galapagos and relied upon his own enclosures in Downe and his corresponding colleagues for observations over time. Despite his fascination with pigeons and the breeding of pigeons, the plants were the source of much of the data that bolstered the associations between adaptation and selection. The reproductive devices of flowering plants, an easily overlooked fact of gardens, occupied his attention as did the actions of earthworms and the taxonomy of barnacles. Beetles, bees, and birds, the pollinators, were a necessary component in the preservation of favored adaptations. The intricate details of these relationships became a foundation for the concept of natural selection. He wrote more books about plants than animals: orchids, insectivorous plants, the role of selection in the plant world, and the movement of plants. His close friendship with JD Hooker gave him access to the growing collections at Kew Gardens and to the details of Hooker's important collecting sojourns in the Himalaya. From Hooker Darwin acquired corroborating information about the variety of plant adaptations to temperature, rainfall, and altitude

from the extraordinary environment of the Himalaya, as well as from his collection of orchids and insectivorous plants in his greenhouse.

In the post Galapagos years other naturalists were at work on the "species problem", in particular Henry Walter Bates and Alfred Russel Wallace. Bates and Wallace traveled to the Amazon region in the 1840s and both provided essential information to Darwin. Bates with his description of mimicry among butterflies in his presentations and publications in the 1850s resulted in his book, *The Naturalist in the Amazons*, published in 1863 which Darwin reviewed. Wallace with his continued studies in Malaysia documented the natural history of another archipelago of islands. Wallace, during his many years of work in the Amazon basin and the Malay Archipelago, came to appreciate the boundaries that exist between ecosystems and divided vast regions of land into ecologic regions. Darwin did not have sufficient time to identify and demarcate ecologic boundaries during his frequent peripatetic journeys through dramatically different landscapes and climates on the coasts and inland regions of the South American continent. The islands of the Galapagos did that for him. Wallace, during his four years in the Amazon, identified the boundaries shaped by rivers and landform. During his several years in the Malay Archipelago he detailed the change in flora and fauna that occurs between the islands of Bali and Lombok which we know now as "Wallace's Line." Darwin corresponded with both Bates and Wallace and welcomed their descriptive data. Wallace pursued the "species problem" with similar intensity as Darwin and, as the story goes, had an epiphany during a malarial fever in which the concept of successful adaptation to a particular environment explained the derivation of new species. His hypothesis was contained in a long letter to Darwin posted from Malaysia in the spring of 1858¹⁰.

The 1858 letter from Alfred Russel Wallace, sent from Ternate, was "the fox in Darwin's backyard." Surprised and anxious, even though he knew that Wallace had been much interested and observant about the "species problem", Darwin consulted with Lyell and Hooker. They decided that the fairest course was to have the paper by Wallace and a paper by Darwin read at the summer meeting of the Linnaean Society and

published in the Society's proceedings. Scientifically and politically, this was a brilliant maneuver. Darwin's paper, heavily weighted with plant and human directed selection data, was complemented and bolstered by Wallace's insight from the field; a classic case of convergent evolution, identical conclusions from different experience and adaptations. We will never know how long Darwin would have waited to publish his long incubating hypothesis. We do know that Wallace's interpretation of his observations and collections over a decade in the wilds of Brazil and Malaysia set out in his 1858 letter precipitated the construction, composition, and ultimate publication of *The Origin of Species*.

Writing the conclusion of this essay on the flights from the Galapagos back to Quito and then back home to Buffalo from Quito, I reminisced about our experience, intrigued by how little the academy and the public attend to the importance of the sense of surprise. I marveled at the delight grandparents and grandchildren found in the blue-footed boobies, curious sea lions, courting male frigate birds, colorful sally lightfoot crabs, and torpid iguanas. Just as the red fox in our backyard startled me into questioning "how and for what purpose", the creatures of the Galapagos set curiosity to work. Three generations of my family were deeply moved by our introduction to the Galapagos.

Darwin was a highly sensitive and emotional man. He could not bear to watch the surgeries without anesthesia as a medical student, he was passionate about nature and living things, and he was appalled at the logical extension of his theory of natural selection with the elimination of a benevolent power creating a stable earthly paradise or an ethereal afterlife. He was susceptible to surprise and its emotions and tried hard, mostly successfully, to examine and to understand the surprises. He was nothing like the fictional icy, logical, dispassionate scientist. Indeed he was a surprise, and for us in the 21st century, he still is. So, this is how the visit of a red fox in my backyard and my recent trip to the Galapagos Islands made me think again of the superb achievements for human thinking that came from the aroused and privileged mind of Charles Darwin, a man who learned how to benefit from science, serendipity and surprise.

REFERENCES

1. DARWIN C. *Journal of Researches into the Geology and Natural History of the Various Countries Visited by H.M.S. Beagle* (Facsimile reprint of the first edition (1839)), 1952, Hafner Publishing Company, New York, pp. 403-4.
2. CHANCELLOR G, VANWYHE J. *Charles Darwin's Notebooks from the Voyage of the Beagle*, 2009, Cambridge University Press, Cambridge, p. 220.
3. DARWIN C. *Beagle Diary*, edited by R.D. Keynes (Reprint of 1988 edition), Cambridge University Press, Cambridge, p. 263, p. 315.
4. DARWIN C. *The Autobiography of Charles Darwin*. Editor Nora Barlow, WW Norton, New York, 1969 (reissued 2005), p. 53.
5. CHAGAS CJR. Nova tripanozomíaze huma. Estudos sobre a morfologia e o ciclo evolutivo do schizotrypanum cruzi. *Mem Inst Osw Cruz* 1909; 1: 159-218.
6. BROWNE J. *Charles Darwin: Voyaging* (Vol. I of a Biography), 1995, Alfred A. Knopf, New York, pp. 211-320.
7. DESMOND A, MOORE J. *Darwin: The Life of a Tormented Evolutionist*, 1994, WW Norton, New York, pp. 212-28.
8. BOULTER M. *Darwin's Garden: Downe House and The Origin of Species*, 2009, Counterpoint, Berkeley, pp. 27-41.
9. ELDRIDGE N. Darwin: *Discovering the Tree of Life*, 2005, WW Norton, New York, pp. 41-68.
10. BROWNE J. *Charles Darwin: The Power of Place* (Volume II of a Biography), 2002, Princeton University Press, Princeton, pp. 3-90.