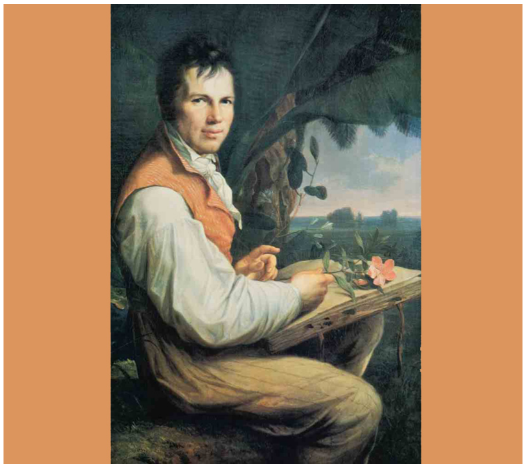

Contributions

Commentary

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A History of the Ecological Sciences, Part 32: Humboldt, Nature's Geographer

Historians of geography claim F. W. H. Alexander von Humboldt (1769–1859) and Carl Ritter (1779–1859) as the two founders of modern geography (Kish 1978:402–419, James and Martin 1981:112–126, Minguet 1997), and there are more places named for Humboldt than for anyone else (Oppitz 1969). During the 1800s several specialized ecological sciences arose, the first of which was Humboldt's vegetational plant geography, in contrast to the floristic plant geography of Linnaeus (Grisebach 1872, Stearn 1968:116–128, Nicolson 1987, Castrillon 1992, Bowler 1993:272–273, Acot 2003). Although Larson (1986:469–472) emphasizes Humboldt's debts to his predecessors, Humboldt was the most important founder of ecological sciences between Linnaeus and Charles Darwin. He was also a great rarity—a wealthy aristocrat who turned his back on the comfort and privilege that he inherited and devoted his life and wealth to science. That he lived almost 90 years was remarkable, given his travels in the tropics and Siberia, and his longevity was a great boon for science. Humboldt's scientific interests and contributions were extremely broad, encompassing practically all of science, and consequently the historical literature on him is vast. The scope of this part of my history seems quite broad, but it only touches a limited part of that literature. There are recent guides to that broader literature: Biermann 1972, Stafleu and Cowan 1976–1988, II:363–371, Hein 1987:310–326, Rupke 2000, Travers 2003; for a bibliography of his 138 scientific papers and six coauthored papers, see the Royal Society of London's *Catalogue of Scientific Papers (1800–1863)* (1869:462–467). Humboldt's numerous biographies include four in English: Bruhns 1873, Terra 1955, Kellner 1963, Botting 1973. The most authoritative biography is in German (Beck 1959–1961). Rupke (2005) provides a survey and critique of Humboldt biographies. There is as yet no collected edition of Humboldt's enormous correspondence, but Heim's bibliography (1987:314) cites 24 published collections. It missed articles that publish only a few letters, such as four to Filippo Parlatore (Rodolico 1968) or just one to Charles Darwin (Barrett and Corcos 1972), and another collection of letters appeared after Heim's bibliography (Humboldt 1993).

Early in his life at his parents' estate near Berlin, he developed a strong interest in natural history, but this did not lead to studies of science, which was unimportant in a German curriculum of the day. He compensated by reading books on exploration, and he especially liked mathematician-explorer Louis Antoine Bouganville's *Voyage autour du monde* (1771), describing his circumnavigation of the world in 1766–1769 (George 1970), and Georg Adam Forster's *A Voyage Round the World* (1777).

Forster (1754–1794) had accompanied his father Johann Reinhold Forster, naturalist on Captain James Cook's second voyage, 1772–1775 (Hoare 1972, Lenz 1980). Karl Ludwig Willdenow (1765–1812) published his *Florae Berolinensis* in 1787, and this book became Humboldt's introduction to botany. In 1788 they met, became close friends, and occasionally collaborated. Willdenow influenced Humboldt's development of an interest in plant geography (Hein 1959, Bylebyl 1976, Browne 1983:38–40, Larson 1986:466–470, Bowler 1993:176–177). When Humboldt went to Göttingen University in 1789, he met Forster, and they also became close friends (Ackerknecht 1955).

Forster and several of the faculty at Göttingen contributed to the continuing development of Humboldt's ideas on plant geography (Larson 1986:464–466, Lenoir 1981:170–174). In the summer of 1790,

Fig. 1. Humboldt as a college student. Daniel Caffe (1756–1815). From De Terra 1955:facing 19.

Humboldt and Forster spent 10 weeks traveling in The Netherlands, Belgium, and England, and then on to Paris, in the midst of a revolution, with which both men sympathized. During his year at Göttingen, Humboldt had studied physics and chemistry, and in 1791 he entered the Freiberg Mining Academy, where he studied mineralogy, mining, and scientific methods (Schellhas 1959, Baumgärtel 1969:24–29, 34–35). He was amazed that mosses and fungi grew in mines, the mosses producing green vegetation from the light of mining lamps. He incorporated this information in his *Flora Fribergensis* (1793), on 260 cryptogamic (nonvascular) plants (Jahn 1969:22–25 + 4 Humboldt plates, Dobat 1987:170–174), which also contained some of his early ideas on plant geography (1793:9–10, footnote; translated by Hartshorne 1958:100)

> *...plant geography traces the connections and relations by which all plants are bound together among themselves, designates in what lands they are found, in what atmospheric conditions they live, and tells of the destruction of rocks and stones by what primitive forms of the most powerful algae, by what roots of trees, and describes the surface of the earth in which humus is prepared.*

Hartshorne said that this was in Humboldt's first major publication; Nicolson (1987:174, 1996:290) states that this was where "Humboldt first publicly set out his programme for a new form of plant geography in 1793." Hanno Beck, in his fine edition of Humboldt's studies on plant geography, discovered other writings by Humboldt on this topic going back to 1790 (Humboldt 1989:33–36).

When Humboldt finished his studies in 1792, he joined the Prussian Department of Mines as an inspector. This gave him an opportunity to study the geological strata in mining areas. He had a great appreciation of measurement and of scientific instruments (Théodoridès and Destombes 1969, Bourguet 1998, Jacques et al. 2003), and he was also adept at devising respirators and safety lamps for miners (illustrated in Botting 1973:30, Kümmel 1987:204). He had never intended to make mining supervision into a career, and after his mother died in 1796, he resigned to pursue science and exploration. In 1796–1797 he planned a trip to the West Indies (Beck 1958). In 1798 he planned to explore Egypt and traveled to Paris to obtain scientific instruments. Neither trip materialized, but while in Paris he met Bougainville, who was planning another voyage around the world and wanted Humboldt to join him.

Fig. 2. Theodolite by Edward Nairne, late 1700s, London.

Humboldt was thrilled, but war aborted that voyage, as it had his plans for Egypt. Nevertheless, Humboldt met Aimé Jacques Alexandre Bonpland (1773–1858), recruited as expedition botanist (Sarton 1943, Stafleu and Cowan 1976–1988, I:274–276, Trystram 1995, Cераruti 2003, Lourteig 2003), who was as disappointed as Humboldt at their aborted expedition. Together, they set out on their own expedition, to Spain, where a German ambassador introduced them to the royal family. Carlos IV was charmed by Humboldt's personality, knowledge, and his fluency in Spanish and readily agreed to allow him and Bonpland to explore Spanish America—at their own expense.

George Basalla (1967) explains that the extent to which science developed in any colony was proportionate to the level of scientific activity in the mother country. There were a significant number of natural history studies being made in Latin America, but since science was poorly supported in Spain, few of these studies were published (Pennell 1945:35–40, Glick and Quinlan 1975:75–77, Canizares-Esquerra 2003, 2005). An exception was a study by Felix de Azara, but his publication owed much to the fact that his brother was Spain's ambassador to France and that he could therefore go to Paris to publish it in a French translation (see below). On the other hand, the natural history studies in South America by the Frenchman Alcide d'Orbigny (1802–1857) were readily published, since he lived in Paris (Tobin 1974).

In a letter which Humboldt wrote to his friend Karl Freiesleben just before they sailed on 5 June 1799, he explained his goal (quoted from Botting 1973:65)

> *I shall try to find out how the forces of nature interact upon one another and how the geographic environment influences plant and animal life. In other words, I must find out about the unity of nature.*

No previous explorer had ever had such an ambitious goal. He was very well equipped for the challenge (Helferich 2004:25)

> *Humboldt gathered perhaps the most sophisticated armamentarium of scientific instruments ever before assembled. Each of the forty-two instruments, nestled in its own velvet-lined box, was the most accurate and most portable of its kind yet devised. There were thermometers for measuring the temperature of air and water, barometers for fixing elevation above sea level, quadrants and sextants for determining geographic position (including a sextant small enough to fit in a pocket), telescopes, microscopes, a balance scale, chronometers, compasses, a rain gauge, substances for performing chemical assays, electric batteries, electrometers (for measuring electric current), a Leyden jar (a glass vessel capable of storing static electricity), theodolites (surveyors' instruments for measuring vertical and horizontal angles), hygrometers (for measuring atmospheric moisture), a dip needle (for measuring variations in the orientation of the earth's magnetic field), and eudiometers (for measuring the amount of oxygen in the air).*

Humboldt's own discussion of these instruments runs to seven pages (1818–1829:34–40).

After their ship, *Pizarro*, reached the Canary Islands on 18 June, they began investigating Teneriffe, the largest island. They ascended Pico de Teide, a volcano 11,500 feet high, and then descended inside to see and smell a recently active volcano. This was the first of Humboldt's many ascents of volcanoes (Sachs 2006:42). Elsewhere they measured the 45-foot circumference of a dragon tree (*Dracaena draco*).

Ever the geographer, Humboldt provided a table on the population of the seven islands for 1678, 1745, 1768, and 1790 (1818–1829:I, 288). The islands suffered from a dearth of fresh water, but wherever there were springs or opportunity for irrigation, crops grew well in fertile soil. The area of all the islands was only one-seventh the size of Corsica, yet the Canaries supported a comparable population. He did not expect these islands to suffer the overpopulation that Malthus discussed (1818–1829:I, 292). On the rest of the voyage they observed flying fish that left the water to escape voracious dolphins, only to be caught by frigatebirds (*Fregata magnificens*) and albatrosses, reminding Humboldt (when writing his memoirs) of herds of South American capybara that fled the water to escape crocodiles, only to be caught by jaguars (1818–1829, II:14–15).

Their five-year expedition in Spanish America covered four geographic regions: (1) the rain forest and mountains of what is now Venezuela, (2) the northern Andes, (3) Cuba, and (4) Mexico. During their travels in the first two regions, their focus was on the flora, fauna, and the environment.

Fig. 3. Humboldt and Bonpland's routes in northern South America. Von Hagen 1945:164.

Fig. 4. Humboldt and Bonpland with some of their baggage. By Eduard Ender. Institut für Geographie und Geoökologie, Leipzig.

In Cuba and Mexico, Humboldt, if not Bonpland, focused on human geography. They had not planned to begin their explorations in Cumaná, but by the time they reached it on 14 July, there was a typhoid fever epidemic aboard the *Pizarro*, and they abandoned ship. They were both excited and entranced by the tropical vegetation and wildlife, and out came Humboldt's notebooks to record everything, including the town's population, temperature, and other environmental variables (1818–1829, II:193–194). He quickly established a distinctive methodology (Walls 1995:98)

> *Humboldt's field method consisted of four principal commandments: explore, collect, measure, connect. His typical tasks during the expedition were to observe the forms and habits of the vegetation, take and calculate geophysical measurements, take exact geographical bearings, and collect plants, animals, and minerals.*

In the countryside, he found that less acreage was planted in crops in proportion to the population than was the case in Europe, and his explanation was that plantains, cassava, yams, and maize yielded much more food per acre than did European crops (1818–1829, III:13–14). He compared the pearl fishery at Cumaná with that of Ceylon (Sri Lanka), and he suspected that the natives of Spanish America were over-fishing. In Ceylon, natives only harvested one month per year, but in Spanish America natives harvested all year. Oysters live 9–10 years, and only in the fourth year do pearls begin to grow. When the Spanish began the pearl fishery, pearls were much bigger than the ones being harvested while Humboldt was in Cumaná (Humboldt 1818–1829, II:274–277, Egerton 1970:344–345).

Their first expedition out of Cumaná, in September, was to the highlands south of town, though they went through some rain forest to get there. One interesting place they explored was a cave near the Mission of Caripe, famous as the nesting place for many guacharos (the oilbird, *Steatornis caripensis*), which Humboldt said was the only known nocturnal frugiferous bird. Indians invaded the cave annually and slaughtered thousands of nestlings for the missionaries, who had the nestlings' fat melted into cooking oil. Humboldt thought the birds there had not been exterminated because the Indians were afraid to go as deeply into the cave as did some of the nesting birds (Humboldt 1818–1829, III:125–130, Egerton 1970:345–346) that navigate in the dark as easily as bats (Griffin 1953). The guacharo's range was broader than Humboldt could have known, encompassing the Guianas, Trinidad, Venezuela, Columbia, Ecuador, Peru, and Bolivia (de Schawensee and Eisnmann 1966:146). A detail Humboldt could have discovered was clutch size: two to four eggs, with median of 2.7; some pairs raise two broods a year (Snow 1961, 1962).

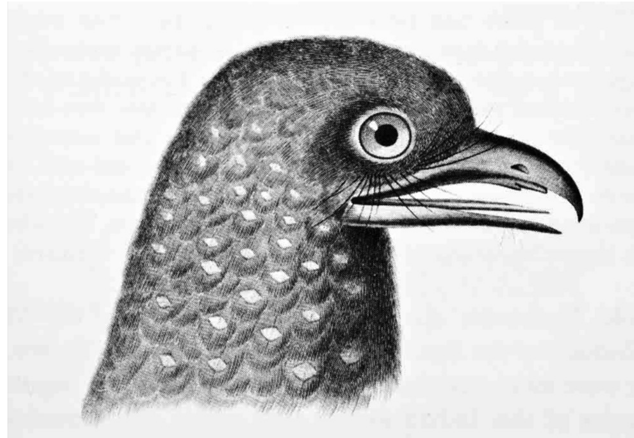

Fig. 5. Guacharo or oilbird, *Steatornis caripensis*. After Humboldt's sketch, engraved by Jean Louis Denis Coutant in 1817. Humboldt and Bonpland 1811–1833, II: Plate 44.

The next expedition, to Rio Orinoco, left in March, 1800. Near Calabozo, they heard of the local five foot long electric "eel" (actually a knifefish), which Linnaeus had named *Gymnotus electricus*. Back in Germany, Humboldt had conducted numerous electrical experiments (Jahn 1969:51–121), and he was eager to explore this fish's electrical organ for hunting and protection. The Indians had an inhumane way of capturing them, but Humboldt was glad to obtain them nevertheless: they herded some 30 horses and mules into pools where the fish lived, which provoked electrical discharges by the fish that sometimes killed the victims or caused them to drown, but also exposed the fish to capture. He and Bonpland conducted experiments, using as victims frogs, turtles, and themselves. Humboldt's instruments failed to detect any electricity or magnetism (Humboldt 1806, 1818–1829, IV:345–377, 1819, Théodoridès 1970:100), but by the 1900s electrical instruments were sensitive enough to measure it (Cutright 1940:278–279, Keynes and Martins-Ferreira 1953). In 1801, on Rio Magdalena, he found a similar species he named *G. equilabiatus,* which did not use electric shocks. He explored more aspects of aquatic life than can be surveyed here, but Stelleanu (1959) has discussed that research.

An even more disturbing annual harvest than that of guacharo eggs was of the eggs of the Arrau turtle (*Podocnemis expansa*) at several islands in the Rio Orinoco near its merger with the Rio Apure. The annual take was converted into 5000 jars of oil, which Humboldt calculated (allowing for broken eggs) represented 33,000,000 eggs from 30,000 turtles (1818–1829, IV:479–494, Egerton

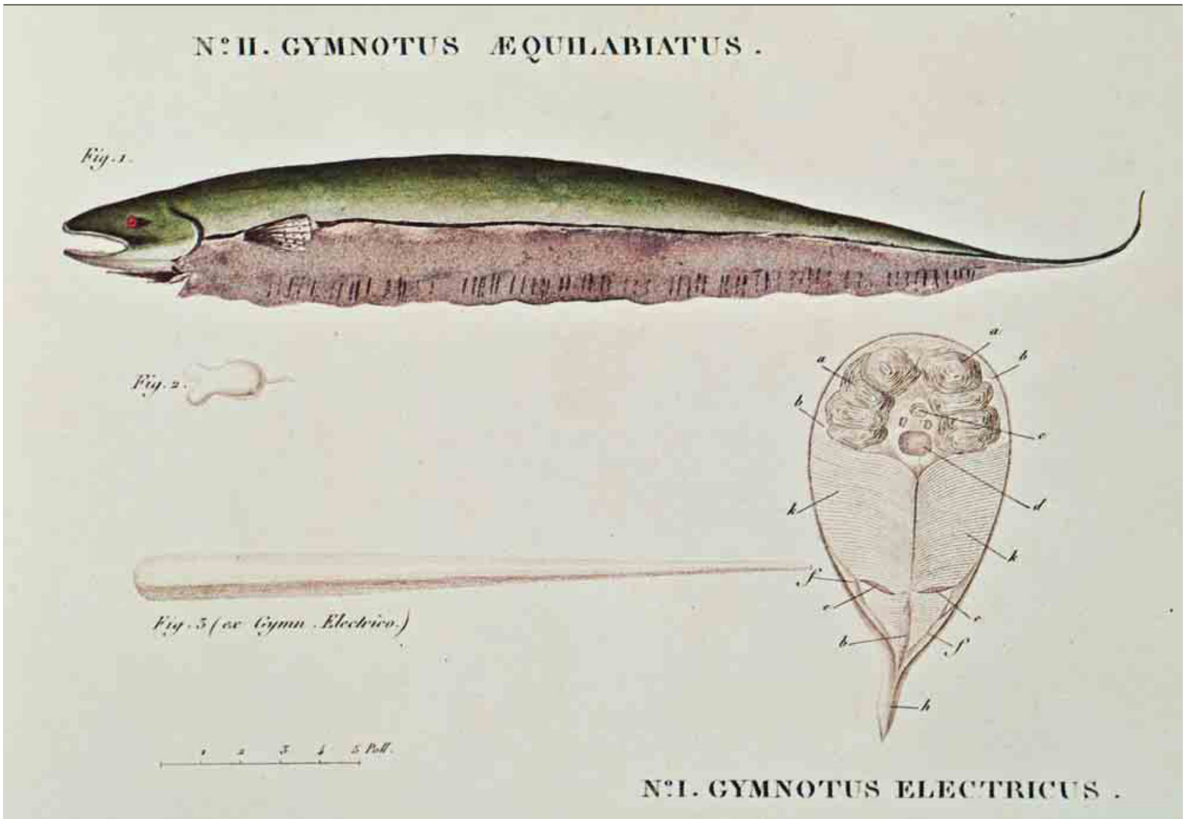

Fig. 6. Two *Gymnotus* (now *Electrophorus*) species: side view of *equilabiatus* and cross section of *electricus*. Drawn by Leopold Müller from Humboldt's sketches, engraved by Louis Bouquet. Humboldt and Bonpland 1811–1833, II: Plate 10.

1970:346–347). Indians also took eggs from *P. dumerilliana*, but since females of this species laid in isolation, not communally, their eggs seemed less vulnerable. In 1850 Henry Walter Bates witnessed an annual harvest of turtle eggs along the Amazon even larger than that which Humboldt had seen along the Orinoco (Bates 1864:345–349, 363–365, Cutright 1940:222).

It was impossible for naturalists to ignore mosquitoes, and Humboldt thought an entomologist should study the tropical species. He started the project by naming and describing in Latin five new species (1818–1829, V:97–98). Missionaries observed that the different species do not associate together, and that different species are active at different times of day. Bites that cause little inflammation in Indians produce large swellings in whites. At the Rio Magdalena some people thought that mosquito bites were a healthful bleeding of the body, but "at the [Rio] Oroonoko, the banks of which are very dangerous to health, the sick accuse the *moschettoes* of all the evils they experience" (1818–1829, V:90–113, quotation, 109). Humboldt agreed with the latter and urged use of mosquito nets. He and Bonpland had escaped malignant fevers (so far), which he thought were not contagious (1818–1829, V:629–630).

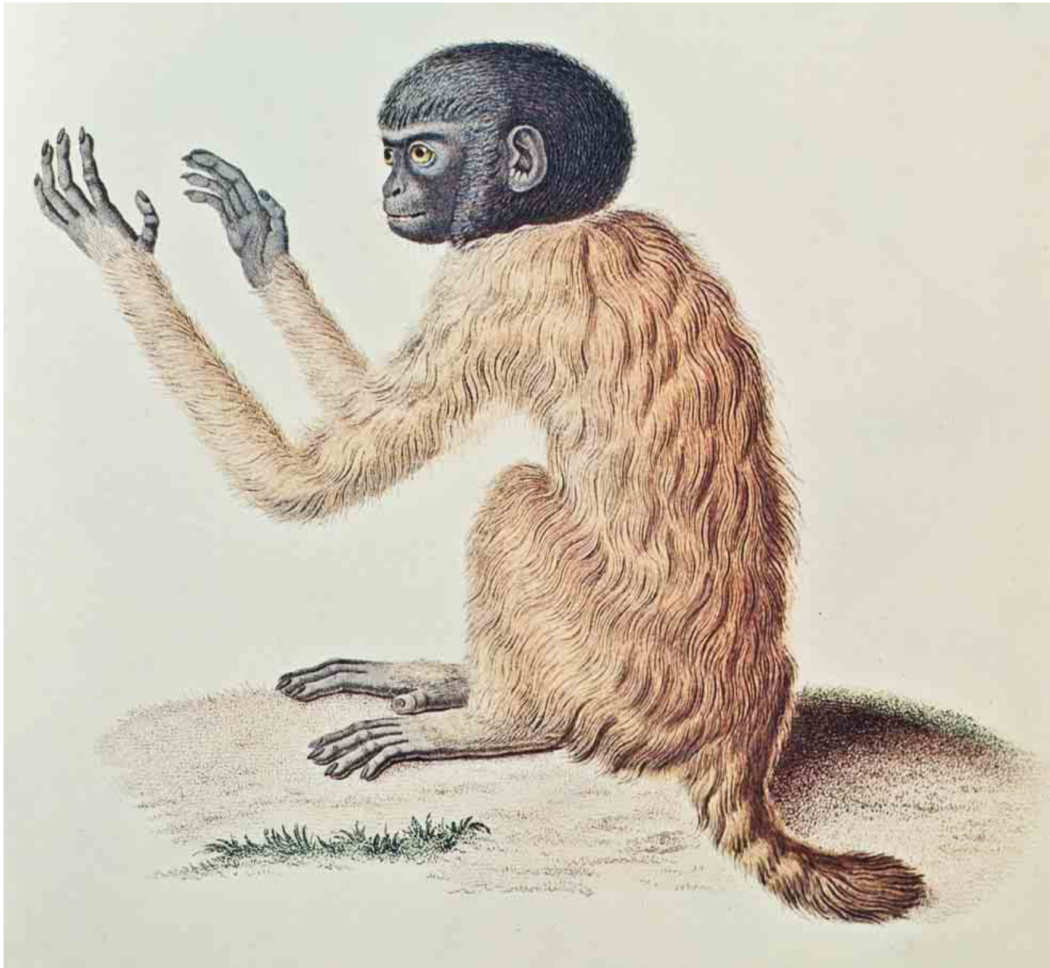

Fig. 7. Black-headed Cacajao (*Simia melanocephala*), by Huet. Humboldt and Bonpland 1811–1833, I: Plate 29.

One goal of their trip up the Rio Orinoco was to verify Charles-Marie de LaCondamine's second-hand report of the existence of a natural canal between that river, flowing north, and Rio Negro, flowing south (Von Hagen 1945:120–124, 1948:128–129). If it existed, it might become important for river commerce. They found the Cassiquiare Canal (Fig. 2), which is 50 leagues (180 miles) long. Christian settlements along it were sparse, with only 200 inhabitants. Humboldt suspected the canal's population was larger before missionaries arrived; their presence probably caused many Indians to withdraw into the woods (1818-1829, V:420). While traveling east for the length of the canal, Humboldt bought a pet black-headed cacajao from the Indians, and he sketched it. After it died from an upset stomach, he kept the skin, and a published illustration (Fig. 7) is in the same pose as his sketch. He listed 46 species of monkey known in America (1811–1833, I:353–368), which is almost half the known species (Cutright 1940:141).

On 24 November 1800 they left Venezuela for Havana to ship their collections to Europe, but found this endeavor complicated by a British blockade. During more than three months in Cuba, they visited various places, for which Humboldt determined latitude and longitude. His memoirs discuss human populations in great detail, and his observations on them are examined closely by Charles Minguet (1997:23-371). While in Havana they read in an American newspaper that the French expedition on which they had wanted to sail had finally left France, but under Captain Nicolas Baudin, not Bouganville. They decided to travel to Lima to join it. On 8 March 1801 they left Cuba for Cartagena, now in Columbia (Fig. 2), on a voyage that usually took little more than a week, but this time lasted 25 days. They stayed three weeks in Cartagena. Volume 7 of the English edition of Humboldt's memoirs is mostly on the Cuban economy, but its last chapter (Chapter 29) is on the voyage and the geography of the Cartagenan region. It is 105 pages long, hardly what one would expect from a short, though time-consuming voyage, and just another geographical essay on a limited region. However, Humboldt was not one to waste time during their delay at sea; this chapter is his contribution to the oceanography and meteorology of the Caribbean Sea (Dove 1872, Körber 1959, Richardson 1980, Verstraete 2003). It was probably the most important contribution to those subjects since Benjamin Franklin had discussed them about a half-century earlier (Chaplin 2006:196-200, 209-212).

That chapter ended his memoirs. Humboldt published his memoirs in French, *Relation historique du voyage aux regions équinoxiales du nouveau continent* (1814-1825), in three volumes, and planned a fourth that never appeared. It would have included their overland trip to Lima, which they reached on 22 October 1802, some 18 months later. Along the way, they learned that Bauhin would not stop in Lima, so they lost their initial sense of urgency. Lacking volume four, his biographers and historians have pieced together accounts of that trip from his other writings, especially *Vues des Cordillères* by him and Bonpland (1810), and Humboldt's correspondence. Although Humboldt's memoirs do discuss plants and vegetation of Venezuela, botany and plant geography were treated in greater detail in other works (Grisebach 1872, Coats 1969:337–341, 368–370, Dobat 1987:176–183). Humboldt and Bonpland collected 60,000 plant specimens and discovered about 3600 new species. Systematic botanists have published fairly exact itineraries of the four parts of their Latin American explorations to identify where they collected plant specimens (Stearn 1968:69–115). They struggled up the Andes to Bogatá, 8600 feet elevation, which they reached on 6 July, and were treated like the aristocrats that Humboldt was, but preferred to ignore. They spent two months with physician–botanist José Celestino Mutis (1732–1808), a Spanish immigrant, whose work was well known in Europe (Coats 1969:362–363, Goodman 1972:223–227, Botting 1973:146–148, Stafleu and Cowan 1976–1988, III:676–677, Vernet 1978, Frías Núñez 1994, Tepaske 1996, Honigsbaum 2001:51–54, Cañizares-Esguerra 2006:122–123). In 1763 Mutis proposed to Carlos III an expedition to study cinchona and other useful plants, and in 1783 he was finally put in charge of the Real Expeditió Botánica del Nuevo Reino de Granada, with a staff of 18, which explored much of what is now Columbia, collecting 20,000 plants. Mutis used powder of cinchona bark to cure Bonpland, who by then suffered from malaria. Humboldt and Bonpland compared plants they had collected with Mutis' vast herbarium. Humboldt named one of his and Bonpland's discoveries *Mutisia grandiflora*, in honor of their host. Later, Humboldt also studied cinchona trees and clearly distinguished three species that even Mutis had confused (Honigsbaum 2001:58–61).

As they traveled south to Popayán, or after arriving there, Humboldt heard about a largely self-taught naturalist-scholar, Francisco José Caldas (1768–1816), from that town, who had independently discovered a way to determine altitude by the boiling point temperature of water (a method already known in Europe). Caldas met Humboldt and Bonpland in Ibarra on 31 December 1801, and they compared their altitude determinations for several places and found impressively close agreement (Arbeláez 1971, Appel 1994, Cañizares-Esquerra 2006:113–116, 124–125). Caldas gave Humboldt a copy of a map he had drawn of Timaná, and in return Humboldt taught Caldas how to use instruments which he had not previously seen, and Bonpland taught him botany. Caldas asked to join Humboldt's expedition, and after Humboldt declined, Caldas joined Mutis' ongoing expedition and made his own important studies on cinchona (Honnigsbaum 2001:53–54). Caldas also made his own phytographic profile of Andes mountains, as he had learned to do from Humboldt (reproduced in Appel 1994:56–57). However, Caldas never published either his cinchona findings nor his phytographic profile, as Spanish authorities executed him in 1816 for participating in an independence uprising. (Humboldt likely would have supported that uprising had it occurred while he was in Spanish America.)

A naturalist whom Humboldt did not meet was Félix de Azara (1742–1821), because he had left South America in 1801 (Alvarez Lopez 1935, Guerra 1970, Goodman 1972:238–242, Beddall 1975, 1983, Glick and Quinlan 1975). He had studied the natural history of Paraguay and Rio Plata, and after stopping over in Spain, he went on to Paris, where his brother was the Spanish ambassador. That connection facilitated the translation of his manuscript on mammals into French and its publication in Paris (1801). Having gained French recognition, he returned to Madrid and succeeded in publishing a revised and enlarged edition in Spanish (two volumes, 1804). In 1809, he published his *Voyages dans l'Amerique meridionale* (four volumes, Paris) that included his natural history in volumes three and four, a work that Darwin cited repeatedly in his own works. An extract from the mammal volume, translated into English in 1837, is reprinted by von Hagen (1948:131–144).

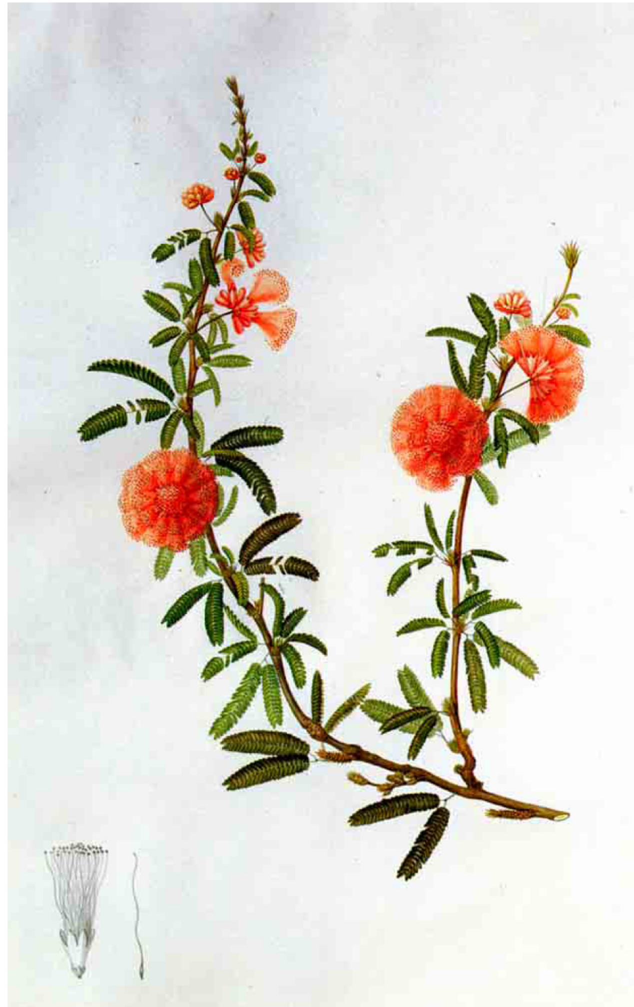

Fig. 8. Red mimosa, *Inga* (now *Calliandra*) *taxifolia*. Water color by Pierre Jean François Turpin. Humboldt, Bonpland, and Kunth 1829–1835:Plate 20.

Humboldt and Bonpland climbed over Quindio Pass, almost 12,000 feet high, to reach Quito, where they stayed six months. A red mimosa (Fig. 8) was a small shrub growing on the slopes of Páramo de Saraguru.

On this trip Humboldt and party indulged his fascination with volcanoes. Although not the most important founder of the science of volcanology, he was its most widely traveled founder (Laudan 1987:188–193, Sigurdsson 1999:124, 164, 224). The most famous episode of the entire four years was his party's ascent of Mount Chimborazo (20,702 feet, 6310 m elevation), south of Quito, which was the tallest known mountain whose elevation had been determined (Figs. 2, 9).

Fig. 9. Mount Chimborazo. Humboldt 1850:frontispiece. This is a small copy of the larger illustration in Humboldt and Bonpland 1810, engraved by Jean-Thomas Thibaut from Humboldt's sketch. The man in the right foreground picking a flower is probably either Humboldt or Bonpland.

They did so on 23 June 1802 and ascended to 18,096 feet (Von Hagen 1945:144–148). It was a pity that Humboldt's memoirs ended before this climactic event. In 1837 he realized this and published an account of Bonpland's and his experiences during their ascent. It includes a description of the vegetation through which they rode (up to the snow line; they then continued on foot). The feral llamas they saw probably had escaped from captivity after a devastating earthquake on 4 February 1797, which had killed 45,000 people (Humboldt 1837:294–296). Bonpland captured a butterfly at 15,000 feet and saw a fly at 16,600 feet. The last green moss was at 14,320 feet, and lichens were found above the snow line at 16,920 feet (Löwenberg 1873:311–315).

Humboldt provided details on the Andean Condor's natural history in his and Bonpland's *Recueil d'observations de zoologie et d'anatomie compare* (1811–1833), including observations on its ability, in search of food, to soar into very thin air, measured at 20,834 feet elevation, and yet it could quickly descend to sea level when it saw food.

It is the largest flying bird, with a wingspan of up to 11 feet, and he concluded that "Of all living beings, it is without doubt the one that can rise at will to the greatest distance from the earth's surface" (Humboldt 1829). Although primarily a scavenger, condors reportedly preyed at times on young sheep, goats, cattle, alpaca, vicuna, and guanacos (Humboldt and Bonpland 1811–1833, I:26–45, Humboldt 1850:210, 239).

Fig. 10. Andean Condor *Vultur gryphus*. Humboldt and Bonpland 1811–1833, I: Plate 8. Illustration by Louis Bouquet.

Humboldt was unimpressed by Lima, yet they stayed there for two months. He learned that Andean farmers used bird guano for fertilizer, and when he visited a pelican colony (Fig. 10) on one of the Lobos de Afuera Islands off the Peruvian coast, he suspected that guano accumulated on such desert islands could become a valuable fertilizer for Europe.

Samples he sent to Europe for testing confirmed his idea, and it did become valuable, thanks to his publicizing the possibility (von Hagen 1945:154–155, Jouanin 2003). Previous published reports of guano fertilizer in accounts of Peru or Chile had not led to its introduction into Europe or North America (Murphy 1936, I:286–288). On 5 December 1802 they left for Guayaquil (Fig. 2), which they reached on 9 January 1803. During that voyage, he determined the exact location of several places along the coast, and he first measured the temperature and speed of an already well-known current that now bears his name. Because of the Humboldt Current, the surface temperature at Callao was only 60°, whereas the air on land was 73°. He later explained that since the moist air from the ocean expanded when it blew inland, its moisture-holding capacity increased and rain did not fall, leading to desert conditions (Humboldt 1817*a*, 1820–1821, von Hagen 1945:156, de Terra 1955:144–146, Goodman 1972:260). When they had attempted, unsuccessfully, to reach the crater of Cotopaxi (18,876 feet, 5896 m elevation) the previous September, it had been inactive, but now, as they sailed along the Ecuadorian coast, they could hear its eruption, 200 miles away. They reached Acapulco on 23 March, and then spent a year exploring central Mexico (map in Helferich 2004:264, Terra 1955:150), visiting volcanoes, mines, and archeological sites. Humboldt also spent much time in the government archives gathering material for his book on the Mexican economy (1811). The Mexicans were so impressed by him that he was offered a ministerial position

Fig. 11. Pelican colony on one of the Lobos de Afuera Islands. Photo: Loren McIntyre, 1985.

in the government. It was tempting, but he needed to prepare his findings and collections for publication, and Paris was best for that.

Before sailing to France, he and Bonpland spent a rewarding five weeks in Philadelphia, Baltimore, and Washington with American scientists and our most scientifically informed president, Thomas Jefferson (Sellers 1980:160–166, Schoenwaldt 1987, Bedini 1990). Jefferson was very interested in their discoveries, and Humboldt left a copy of his map of New Spain (Mexico) in Washington. Humboldt and Bonpland then sailed to France, reached Bordeaux on 1 August 1804, and soon settled in Paris to organize their vast collections and notes and to publish 30 volumes of their findings (Limoges 1980:212).

Those volumes were written largely by Humboldt, but Bonpland's name appears as coauthor of about a third of them. This ever-faithful field naturalist did good work on some of the early volumes (Stafleu and Cowan 1976–1988, I:274–276, Drouin and Huet 2002), but he disliked preparing field notes for publication and eventually abandoned the task (Hossard 2001:23–50). It seems fair to just speak here of Humboldt and his ideas without also referring to Bonpland's ideas. Since they had 60,000 American plant specimens to consider, Humboldt realized he needed another botanical collaborator, and in 1813 he brought to Paris from Berlin Carl Sigismund Kunth (1788–1850) to study the collections and publish systematic accounts (Stearn 1968:140–151, Stafleu and Cowan 1976–1988, II:692–698). Liberated, Bonpland returned to South America in 1816 (Coats 1969:356–357, Hossard 2001). Humboldt's (and

Fig. 12. Aimé Jacques Alexandre Bonpland, by R. Fugmay. Museum of Botany and Pharmacology of the Faculty of Sciences and Medicine of Buenos Aires, Argentina.

Bonpland's) first volume, *Essai sur la géographie des plantes, accompagné d'un tableau physique des regions équinoxiales, et servant d'introduction à l'ouvrage* (1807), has only 155 pages. By "introduction to the work," he meant to all the following volumes. Humboldt certainly began with a dramatic flourish, because facing the title page of the *Essai* is a foldout "tableau" (Humboldt's word in the French version) of Chimborazo and Cotopaxi, as a visual introduction to what historians now call "Humboldtian science" (Cannon 1978:73–110, Dettelbach 1994), a science of correlations. It was probably the most original and most important diagram for ecological sciences in the 1800s (Fig. 13). In most copies of the *Essai* it is uncolored, but one could pay extra for a colored copy.

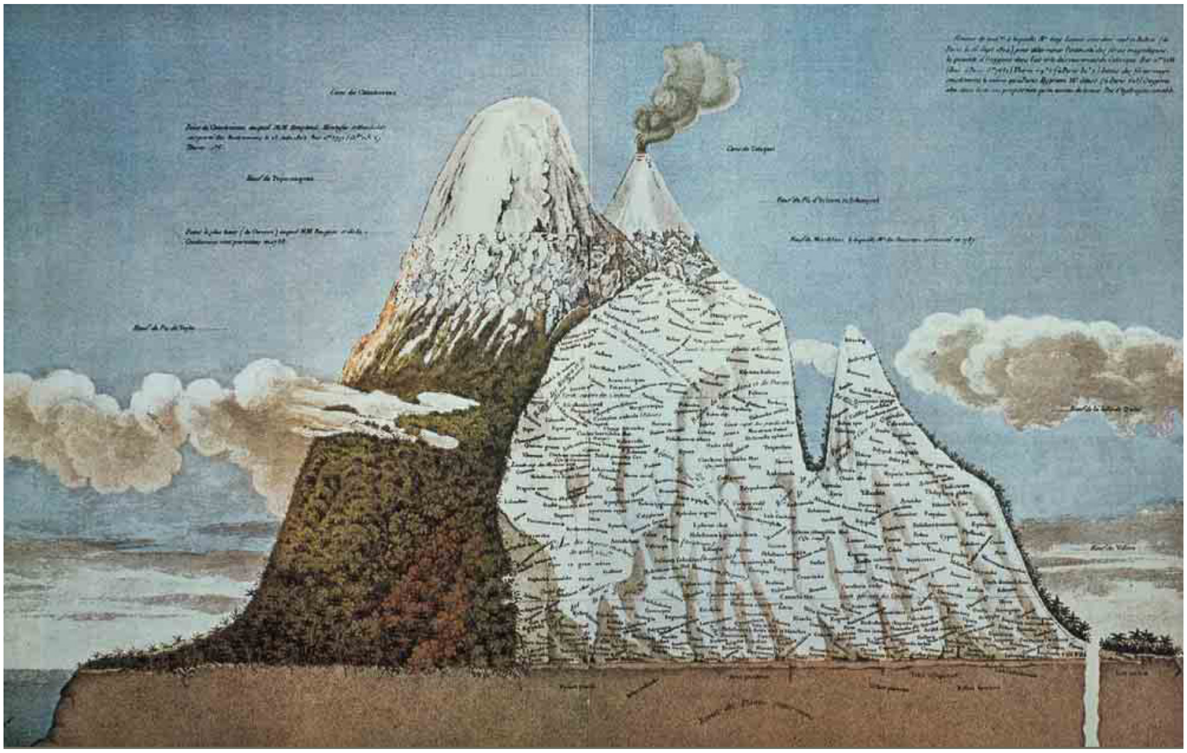

Fig. 13. "Géographie des plantes équinoxiales. Tableau physique des Andes et pays voisins." Shown is the central portion of the diagram-chart of Chimborazo and Cotopaxi, without the 20 flanking columns of data divided between the two sides. Humboldt and Bonpland 1807:Frontispiece.

In 1977, when I had Arno Press reprint a photo facsimile edition of the *Essai*, I expected the press to include a foldout reproduction of the tableau, as AMS Press had done (1966) when reprinting a later (simplified) version of it that was included in volume six of Williams' translation of Humboldt's *Personal Narrative*. I only discovered that Arno Press omitted it when I received my copy. Color photographs of the German version of the tableau are reproduced in a large size by Heim (1987:70–71) and in a smaller foldout in Beck's edition of Humboldt's plant geography writings (Humboldt 1989); Acot (2003:91) provides a color photograph of the French version.

This tableau nicely illustrates Humboldtian science. There is a massive amount of data presented in a clear way to symbolize the influences of the physical environment on plants. Two columns on each side of the tableau give elevation in meters and in toises. Omitting those four columns, Dettelbach (1996:270) translates into English the headings of the other 16 columns:

1 *terrestrial refraction at an angle of 50^o, at zero centigrade;*
2 *distances at which mountains of a given elevation are visible from the sea, subtracting for refraction;*
3 *elevations of various European and American landmarks, in meters;*
4 *frequency of electrical phenomena, as measured by Volta's electrometer;*

5 *types of agriculture at different elevations;*
6 *the decrease in force of gravity, measured by the frequency of a pendulum in a vacuum;*
7 *blueness of the sky, in degrees of Saussure's cyanometer;*
8 *the decrease in humidity, in degrees of Saussure's hygrometer;*
9 *pressure measured in heights of the barometric column; then, jumping Chimborazzo,*
10 *maximum, minimum, and mean temperatures in degrees centigrade;*
11 *chemical composition of the atmosphere, measured by Volta's eudiometer;*
12 *the elevation of the permanent snow line at various latitudes;*
13 *animal life at different elevations;*
14 *the temperature at which water boils at different elevations;*
15 *the geological structure at different heights;*
16 *the variation of the intensity of light, taking intensity in a vacuum as = 1.*

With Humboldt's passion for instruments and measurements, one might imagine the construction of these columns of data from his field notes was routine. It was not. He enlisted the assistance of four of France's leading physical scientists to ensure their accuracy (Dettelbach 1994:292). Among the four was François Arago (1786–1853), who became Humboldt's closest friend (Hahn 1970).

How did one use the tableau? One might choose a particular plant species living at a certain elevation, and determine its mean temperature, humidity, light intensity, and characteristic animals, by picking out its name on the cutaway mountainside and using a straightedge to line up its name with the data in the flanking columns. However, one had to decide for oneself whether, at that elevation, factors such as the boiling point of water or the density of oxygen were significant for that species. His text distinguished between solitary and social plant species, with temperate regions having more of the latter than the tropics did. He noted a correlation between elevation and latitude in the range of many species. Chimborazo had four floral zones, with a tropical flora at its base, succeeded as one ascended by temporal, boreal, and arctic floras. More generally, Humboldt distinguished seven vegetation regions, which Dobat (1987:191) summarizes:

1 *subterranean plants (cryptogams in caves and mines, algae on the seabed);*
2 *palms and plantains (0–1000 m);*
3 *"treelike ferns", which partly coincides with the "cinchona region" (400–1600 m);*
4 *oak (1700 to around 3000 m);*
5 *Wintera and the escallonia (2800–3300 m);*
6 *alpine plants (3300–4100 m);*
7 *grasses (4100–4600 m).*

In Europe, Humboldt identified the Mediterranean Sea and the Pyrenees Mountains as barriers to the spread of species north or south. He thought that plant geography could assist geology by indicating former continental connections. For example, there is a similarity in the species found in east Asia on one side of the Pacific, and those of California and Mexico on the other. He noted that as humans destroy forests, regional humidity diminishes. Lichens grow in all latitudes, and they seem less dependent on climate than on the rocks they inhabit. To understand plant migration, one must use fossil evidence. He listed 15 physiognomic forms of plant groups—their general appearance—including lichens, mosses, grains, palms, evergreen trees, and deciduous trees (Troll 1969). (He repeated these with more details in a general work for the public, *Ansichtaen der Natur mit wissenschaftlichen Erläuterungen* [1808, English 1850:210–352].) He thought that changes in the intensity of sunlight over long periods might explain the past expansion and contraction of the tropics.

Ecologist Roger Dajoz summarized Humboldt's contributions to plant geography (1984:6)

> *He was the first to establish the notion of association, to propose a classification of vegetal "life forms," to create the concept of isothermal line and to prove the existence, in the mountains, of different vegetation zones, the temperature being the main determining factor.*

Humboldt's *Essai* was, in the terms of Thomas Kuhn (1970), a paradigm for a new science. It was quite successful in calling attention to vegetational plant geography and in inspiring others to follow his paradigm in their own work. However, if one compares it to Lavoisier's paradigm for chemistry, *Traité élémentaire de chimie* (1789), or to Lyell's for geology, *Principles of Geology* (1830–1833), it seems less impressive. One reason is that they were reorienting existing sciences, and Humboldt was inventing a rather new science: vegetational, as opposed to floristic, plant geography. He did lay out several potential research programs, but a coherent science would only be achieved after Augustin Pyramus de Candolle broadened the paradigm (Egerton 1968:231–232, Dajoz 1984:13–19, Drouin 1998:9–115, 2008:170–173, Matagne 1999:85–88).

A research program that he and many of his followers favored was to make statistical determinations of the ratios of the species of different families to each other in different regions (Browne 1983:58–62). He explained to the French Institute what was being learned (1816:447–448)

> *…certain forms become more common from the equator towards the pole, like the ferns, the glumaceae* [grasses, sedges, rushes]*, the ericinae, and the rhododendrons. Other forms on the contrary increase from the poles towards the equator…such are therubiaceae, the malvaceae, the euphorbia, the leguminous and the composite plants. Finally, others attain their maximum even in the temperate zone, and diminish also towards the equator and the poles. Such are the labitaed plants, the amentaceae, the cruciferae, and the umbelliferae.*

Aside from such generalizations, the research involved determining such data as: "The grasses form in England 1/12th, in France 1/13th, in North America 1/10th, of all phanerogamous plants." A reason for the popularity of this line of research was that most of the data were already available in national flora manuals; one had merely to do the tabulations. To understand the causes of similarities and differences between places, one needed to know their respective quantities of heat. Here, for the first time, he wrote (1816:448):

> *…in organic nature, the forms present constant relations under the same* isothermal parallels, i.e. *on curves traced by points of the globe which receive an equal quantity of heat.*

He greatly expanded this thought the following year in his lengthy article, "Sur les lignes isothermes et de la distribution de la chaleur sur le globe," which was later translated into English (1820–1821, reprinted in Egerton 1977). However, his often-reprinted chart of isothermal lines for the Atlantic Ocean between Europe and America was not published with the French article or the English translation. Oddly, it appeared with an abstract of this article in another journal (Robinson and Wallis 1967). He also developed charts with isobar lines to indicate barometric pressure (Browne 1983:47). Such charts were among his numerous contributions to meteorology and climatology (Dove 1892, Körber 1959).

Humboldt also expanded his tableau concept by creating three new ones. In the "Prolegomena" (preface or introduction) to *Nova Genera et Species Plantarum* (1816–1826), he has a tableau comparing the vegetation of five mountains at different latitudes, from the equator to Lapland. And in *Atlas géographique et physique du Nouveau Continent* (1813–1834), Plate 1 is a tableau of the plants of Pico de Teide on Teneriffe, and Plate 9 is a different version of the 1807 one of Chimborazo, its plants and elevations of adjacent regions. Dobat (1987:186–192) reproduces all three in color. Beck also reproduces in color as a foldout the one from *Nova Genera et Species Plantarum* in his edition of the works on plant geography (Humboldt 1989).

Humboldt's 43-page "Prolegomena" to *Nova Genera et Species Plantarum* applied the concepts of the *Essai* (1807) to the whole world, but that was a brief treatment of a vast subject, and so he expanded it into a 250-page book that has an impressive synthesis of scientific literature (Humboldt 1817*b*). However, if the scope of his plant geography had been adequate for a new science, this book should have been the final stimulus needed. But nothing happened until August Pyramus de Candolle added a new dimension to plant geography in 1820 (discussed in Part 33).

Animal geography had a more gradual, less dramatic, origin. As we have seen (Egerton 2007), Buffon contributed to animal geography in his *Histoire naturelle, générale et particulière* (22 volumes, 1749–1789) and *Histoire naturelle des oiseaux* (9 volumes, 1770–1783). A German professor of mathematics and physics in Brunswick, Eberhard August Wilhelm Zimmermann (1743–1815), explored the subject in much more detail in two substantial works (1777, 1778–1783). He decided that both Buffon and Linnaeus had been too speculative in their discussions and concentrated on providing much more data as a basis for this science (Hofsten 1916:252–255, Bodenheimer 1955, Browne 1983:25–26, Larson 1986:453–454, 473–482). We have also seen that Pallas made significant contributions to both plant and animal geography in the last decades of the 1700s and in the first decade of the 1800s (Egerton 2008). Professor Gottfried Reinhold Treverinus (1776–1837) of Bremen (Smit 1976) also discussed the distribution of plants and animals and the influence of external conditions in volume 2 of his great synthesis, *Biologie* (1802–1822). Humboldt himself contributed to animal geography a list and description of some new species and data on their distributions (Carus 1872), published partly in his memoirs and more systematically in *Recueil d'observations de zoologie et d'anatomie compare* (two volumes, 1811–1833). To publish those volumes, he first needed a zoologist to identify and classify his animal specimens, and he obtained the assistance of Achille Valenciennes (1794–1865), who was actually born in the Muséum d'Histoire Naturelle in Paris (Appel 1976). They became lifelong friends, and 70 letters from Humboldt to him are published (Théodoridès 1965).

Humboldt might have remained in Paris for the rest of his life, but Friedrich Wilhelm IV wanted him back in Berlin as his advisor. Humboldt's vast publishing enterprise was his excuse for staying in Paris, but in 1827, with his private fortune about exhausted, and even though his 30 volumes were not yet completed, he bowed to his king's wishes and returned to Berlin. Humboldt was a fervent democrat,

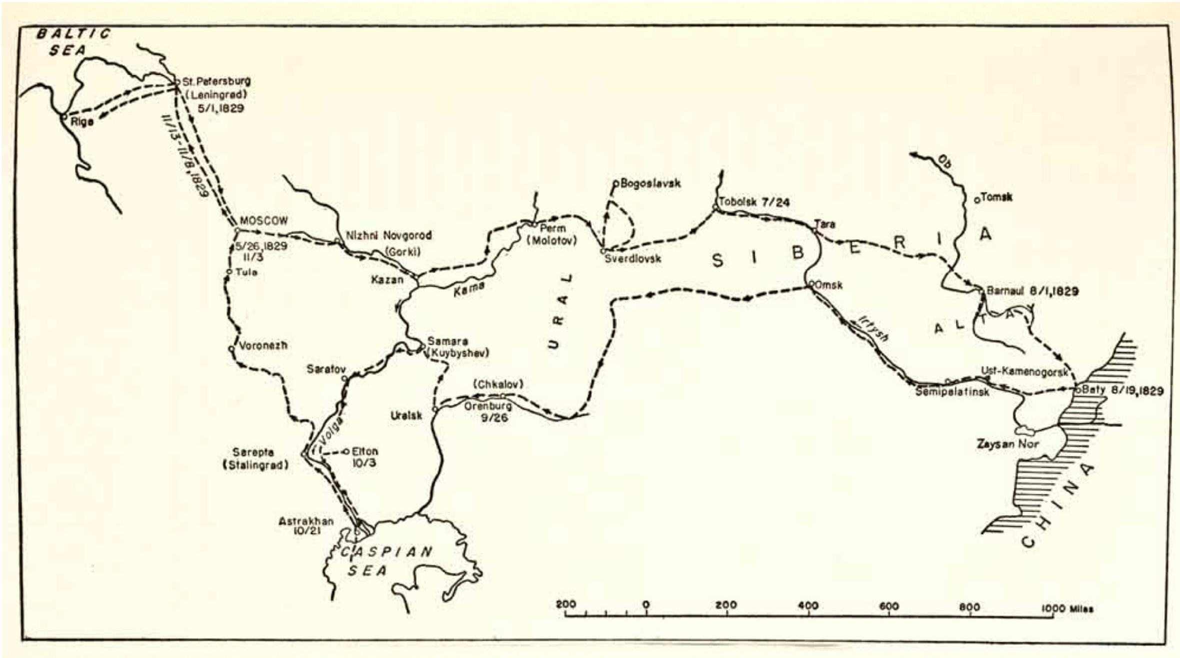

Fig. 14. Humboldt's itinerary in Russia in 1829. De Terra 1955.

who greatly admired the United States, excepting its slavery, and he never enjoyed the company of conservative Prussian aristocrats. Nevertheless, he accepted the invitation of Nicholas I to go to even more repressive Russia to advise on running its mines, because he had long wanted to explore eastern Russia, and this was his only chance. He left Berlin on 12 April 1829; he was gone for almost six months and traveled 9700 miles (Löwenberg 1873:365–390, De Terra 1955:283–303 [with map; see my Fig. 14], Kellner 1963:131–146, Botting 1973:238–252 [with map]). This journey was nothing like his explorations in Spanish America, which had been a fairly small, private adventure. In Russia, he was an international celebrity and was treated as such, and his studies were limited mostly to geology, mining, geography, and climatology. However, he brought along the German zoologist Christian Gottfried Ehrenberg (1795–1876), who had participated in an expedition to Egypt in 1820–1825, and who now collected specimens for the St. Petersburg, Berlin, and Paris museums (Jahn 1971, Winsor 1976:28–50). Humboldt also took along the German mineralogist Gustav Rose (1798–1873), who published a two-volume account of their explorations (1837–1842), with their findings in geology, and mineralogy (Pabst 1975). Expeditions during the 1700s had already surveyed the flora and fauna of some places they visited (Egerton 2008). Humboldt would not explore without his instruments, enabling him to determine latitudes, longitudes, altitudes, climate, and magnetic variations. These data were incorporated into his *Asie Centrale: recherches sur les chaines de montagnes et la climatologie comparée* (three volumes, Paris, 1843), which Kellner (1963:147–164) nicely summarizes and critiques. Humboldt persuaded the Russian government to establish a series of meteorological stations from west to east across the country—one of the first, if not the first, such system that a government organized.

Being a diligent and skillful worker throughout his long life, and never distracted by raising a family, Humboldt became the most productive scientist in history. Eventually he was eclipsed at climbing a higher mountain than anyone else, but it is unlikely that anyone will ever eclipse his scientific publishing record (Löwenberg 1872). His vision of earth sciences, including what we call ecology, was ultimately achieved, not by any individual who aspired to measure and evaluate every physical variable and its effects upon all forms of life in a region, as he did, but by international cooperative efforts among scientists, which he, more than anyone else, promoted (Kellner 1963:165–184). He organized the second annual meeting of the Versammlung deutscher Naturforscher und Ärzte in Berlin in the summer of 1823, and 600 scientists attended, including representatives from Britain, Denmark, and Sweden (Botting 1973:235–237). It inspired national organizations of scientists elsewhere, including the British Association for the Advancement of Science. The International Geophysical Year (July 1957–December 1959) and the International Biological Program (July 1964–July 1974) were projects that matched Humboldt's vision, whether or not he inspired them (Egerton 1983:268–270).

Humboldt's influence was enormous, thanks to his publications, personal relationships, extensive correspondence, and occasional talks (Jahn 1965, Beck 1969*a*, Egerton 1979, 2003:24–27, Goetzmann 1986:155–191, Drouin 1993:71–73, Walls 1995:95–108, Nicolson 1996, Sachs 2006). He might have been even more influential had he accepted a professorship at the University of Berlin, founded in 1810 by his brother Wilhelm (now Humboldt University), and trained new scientists himself. He was, however, a patron to young scientists in a variety of ways (Beck 1987). The closest he came to teaching was his delivery of two sets of lectures in Berlin, the first set during the winter of 1806–1807, which was published as *Ansichten der Natur* (1808; enlarged edition 3, 1849, translated into English twice: 1849, 1850), and in the winter of 1827–1828, 61 lectures which, when published, became his last major work, *Kosmos* (5 volumes, Stuttgart, 1845–1862, English, 5 volumes, 1848–1858). He began the *Kosmos* lectures by saying that the most important result of science is "a knowledge of the chain of connection, by which all natural forces are linked together and made mutually dependent upon each other" (1874, I:23 see Meyer-Abich 1969*a*, *b*). *Kosmos* emphasized physical sciences but did summarize some of his work on plant and animal geography (1874, I:346–351); and if he had had the time and energy to write a contemplated sixth volume, he might have provided more biological details of ecological interest. His memoirs and works written for the public were important for disseminating his views and for recruiting young men for science (Drouin 2003, Sachs 2006). Others helped disseminate Humboldt's work as well. There are more portraits of him than of any other scientist (Lange 1959, Nelkin 1980). Popularizations of his life and work are so numerous they are beyond listing. Most of them focus upon his Latin American adventures (such as Cutright 1940:7–11, von Hagen 1945, Goodman 1972:245–263, McIntyre 1985), but some summarize his whole career (such as Adams 1969:198–236, Botting 1973). A branch of medical geography arose that adopted his methods and outlook and is now called "Humboldtian medicine"(Rupke 1996). The Scottish naturalist, William MacGillivray, published a one-volume condensation of Humboldt's memoirs, in a pocket-sized edition (1833), with a map of Rio Orinoco and five illustrations. Charles Darwin was only the most famous of the many naturalists who were inspired by Humboldt (Dunken 1959, McKinney 1972:4–5), and he used Humboldt's memoirs as a model for the *Journal of Researches*, describing his *Beagle* voyage (Théodoridès 1968, Egerton 1970, Barrett and Corcos 1972).

Literature cited

Ackerknecht, E. H. 1955. George Forster, Alexander von Humboldt and ethnology. Isis 46:83–95.

Acot, P. 2003. Au Chimborazo, la géographie des plantes. Pages 84–91 *in* Humboldt et Bonpland, 1799–1804: une aventure savante aux Amériques. Special issue of Musée des Artes et Métiers–La Revue, numbers 39–40.

Adams, A. B. 1969. Eternal quest: the story of the great naturalists. G. P. Putnam's Sons, New York, New York, USA.

Alvarez Lopez, E. 1935. Félix de Azara. M. Aguilar, Madrid, Spain.

Appel, J. W. 1994. Francisco Jos de Caldas: a scientist at work in New Granada. American Philosophical Society Memoirs 84: Part 5.

Appel, T. 1976. Achille Valenciennes (1794–1865), zoology. Dictionary of Scientific Biography 13:554–555.

Arbeláez, E. P. 1971. Francisco José de Caldas (1768–1816), botany, astronomy, geography. Dictionary of Scientific Biography 3:16.

Azara, F. de. 1802. Apuntamientos para la historia natural de los quadrúpedos del Paraguay y Rio de la Plata. Two volumes. Viuda de Ibarra, Madrid, Spain. Reprint 1978 in one volume. Arno Press, New York, New York, USA.

Barrett, P. H., and A. F. Corcos. 1972. A letter from Alexander Humboldt to Charles Darwin. Journal of the History of Medicine and Allied Sciences 27:159–172.

Basalla, G. 1967. The spread of western science. Science 156:611–622.

Bates, H. W. 1864. The naturalist on the River Amazons. John Murray, London, UK. Reprint 1962. University of California Press, Berkeley, California, USA.

Baumgärtel, H. 1969. Alexander von Humboldt: remarks on the meaning of hypothesis in his geological researches. Pages 19–35 *in* C. J. Schneer, editor. Toward a history of geology. M.I.T. Press, Cambridge, Massachusetts, USA.

Beck, H. 1958. Das Ziel der grossen Reise Alexander von Humboldts. Erdkunde 12:42–58. Reprinted in Stearn 1968.

Beck, H. 1959–1961. Alexander von Humboldt. Two volumes. Steiner, Wiesbaden, Germany.

Beck, H. 1969*a*. Hinweise auf Gespräche Alexander von Humboldts. Pages 249–276 *in* H. Pfeiffer, editor. Alexander von Humboldt: Werk und Weltgeltung. R. Piper, Munich, Germany.

Beck, H. 1969b. Zur Geschichte der Alexander-von-Humboldt-Forschung. Pages 483–496 *in* H. Pfeiffer, editor. Alexander von Humboldt: Werk und Weltgeltung. R. Piper, Munich, Germany.

Beck, H. 1987. Alexander von Humboldt as a patron—a second Maecenas. Pages 301–307 *in* W.-H. Hein, editor. Alexander von Humboldt: life and work. C. H. Boehringer Sohn, Ingelheim am Rhein, Germany.

Beddall, B. G. 1975. "Un naturalista original:" Don Félix de Azara, 1746–1821. Journal of the History of Biology 8:15–66.

Beddall, B. G. 1983. The isolated Spanish genius—myth or reality? Félix de Azara and the birds of Paraguay. Journal of the History of Biology 16:225–258.

Bedini, S. A. 1990. Thomas Jefferson: statesman of science. Macmillan, New York, New York, USA.

Biermann, K.-R. 1972. Friedrich Wilhelm Heinrich Alexander von Humboldt (1769–1859), natural science. Dictionary of Scientific Biography 6:549–555.

Bodenheimer, F. S. 1955. Zimmermann's *Specimen Zoologiae Geographiae Quadrupedum*, a remarkable zoogeographical publication of the end of the 18th century. Archives Internationale d'Histoire des

Sciences 8:351–357.
Botting, D. 1973. Humboldt and the cosmos. Harper and Row, New York, New York, USA.
Bourguet, M.-N. 1998. La république des instruments: voyage, measure et science de la nature chez Alexandre de Humboldt. Volume 2, pages 405–435 *in* E. François, M. C. Hoock-Demarle, R. Meyer-Kalkus und M. Werner, editors. Marianne-Germania: Deutsch-französischer Kulturtransfer im europäischen Kontext; Les transferts culturels France-Allemagne et leur contexte européen, 1789–1914. Two volumes. Leipziger Universitätsverlag, Leipzig, Germany.
Bowler, P. J. 1993. The Norton history of the environmental sciences. Norton, New York, New York, USA. Also published as The Fontana history of the environmental sciences. Fontana, London, UK.
Browne, J. 1983. The secular ark: studies in the history of biogeography. Yale University Press, New Haven, Connecticut, USA.
Bruhns, K., editor. 1873. Life of Alexander von Humboldt. J. Lassell and C. Lassell, translators. Two volumes. German edition of 1872 is in 3 volumes; English edition omits volume 3 and Löwenberg's bibliography in volume 2. Longmans, Green, London, UK.
Bylebyl, J. J. 1976. Karl Ludwig Willenow (1765–1812), botany, historical phytogeography. Dictionary of Scientific Biography 14:386–388.
Cañizares-Esquerra, J. 2006. Nature, empire, and nation: explorations of the history of science in the Iberian world. Stanford University Press, Stanford, California, USA.
Cannon, S. F. 1978. Science in culture: the early Victorian period. Dawson and Science History Publications, New York, New York, USA.
Carus, J. V. 1872. Zoologie und vergleichende Anatomie. Pages 269–300 *in* Alexander von Humboldt: eine wissenschaftliche Biographie. Volume 3. K. Bruhns, editor. F. A. Brockhaus, Leipzig, Germany.
Castrillon, A. 1992. Alexandre de Humboldt et la géographie des plantes. Revue d'Histoire des Sciences 45:419–433.
Cerruti, C. 2003. Aimé Bonpland, botaniste et aventurier. Pages 38–47 *in* Humboldt et Bonpland, 1799–1804: une aventure savante aux Amériques. Special issue of Musée des Arts et Métiers--La Revue, numbers 39–40.
Chaplin, J. E. 2006. The first scientific American: Benjamin Franklin and the pursuit of genius. Basic Books, New York, New York, USA.
Coats, A. M. 1969. The plant hunters: being a history of the horticultural pioneers, their quests and their discoveries. McGraw-Hill, New York, New York, USA.
Cutright, P. R. 1940. Great naturalists explore South America. Macmillan, New York, New York, USA.
De Schauensee, R. M., and E. Eisenmann. 1966. The species of birds of South America and their distribution. Livingston, Narbeth, Pennsylvania, USA.
De Terra, H. 1955. Humboldt: the life and times of Alexander von Humboldt, 1769–1859. Alfred A. Knopf, New York, New York, USA.
Dettelbach, M. 1994. Humboldtian science. Pages 287–304, 482–484 *in* N. Jardine, S. Secord, and E. Spary, editors. Cultures of natural history. Cambridge University Press, Cambridge, UK.
Dettelbach, M. 1996. Global physics and aesthetic empire: Humboldt's physical portrait of the tropics. Pages 258–292 *in* D. P. Miller and P. H. Reill, editors. Visions of empire: voyages, botany, and representations of nature. Cambridge University Press, Cambridge, UK.
Dettelbach, M. 2005. The stimulus of travel: Humboldt's physiological construction of the tropics. Pages 43–58 *in* F. Driver and L. Martins, editors. Tropical visions in an age of empire. University of Chicago Press, Chicago, Illinois, USA.
Dobat, K. 1987. Alexander von Humboldt as a botanist. Pages 167–193 *in* W.-H. Hein, editor. Alexander

von Humboldt: life and work. C. H. Boehringer Sohn, Ingelheim am Rhein, Germany.
Dove, H. W. 1872. Meteorologie. Volume 3, pages 90–101 *in* K. Bruhns, editor. Alexander von Humboldt: eine wissenschaftliche Biographie. F. A. Brockhous, Leipzig, Germany.
Drouin, J.-M. 1993. L'écologie et son histoire: réinventer la nature. Flammarion, Paris, France.
Drouin, J.-M., editor. 1998. Botanical geography. Volume one, pages 9–149 *in* The European origins of scientific ecology (1800–1901). P. Acot, editor. B. P. Hamm, translator. Editions des Archives Contemporaines, Gordon and Breach, France.
Drouin, J.-M. 2001. Analogies et contrastes entre l'expédition d'Egypt et le voyage d'Humboldt et Bonpland. História, Ciências, Saúde—Manguinhos 8 (supplement):839–861.
Drouin, J.-M. 2003. Humboldt et la popularization des sciences. Pages 54–63 *in* Humboldt et Bonpland, 1799–1804: une aventure savante aux Amériques. Special issue of Musée des Arts et Métiers—La Revue, numbers 39–40.
Drouin, J.-M. 2008. L'herbier des philosophes. Editions du Seuil, Paris, France.
Drouin, J.-M. and E. Huet. 2002. Biogéographie et systématique dans les *Plantes equinoxiales* d'Alexandre de Humboldt et Aimé Bonpland (1808–1809). Bulletin d'histoire et d'épistemologie des sciences de la vie et d'épistemologie des sciences de la vie 9:25–38.
Dunken, G. 1959. Die Geschichte der [Alexander von] Humboldt-Stiftung für Naturforschung und Reisen. Pages 161–179 *in* Alexander von Humboldt 14.9.1769-6.5.1859: Gedenkschrift zur 100. Wiederkehr seines Todestages. Alexander von Humboldt-Kommission der Deutschen Akademie der Wissenschaften zu Berlin, editor. Akademie-Verlag, Berlin, Germany.
Egerton, F. N. 1968. Studies of animal populations from Lamarck to Darwin. Journal of the History of Biology 1: 225–259.
Egerton, F. N. 1970. Humboldt, Darwin, and population. Journal of the History of Biology 3:325–360.
Egerton, F. N., compiler. 1977. Ecological phytogeography in the nineteenth century. Arno Press, New York, New York, USA.
Egerton, F. N. 1979. Hewett C. Watson, Great Britain's first phytogeographer. Huntia 3:87–102.
Egerton, F. N. 1983. The history of ecology: achievements and opportunities, part one. Journal of the History of Biology 16:259–310.
Egerton, F. N. 2003. Hewett Cottrell Watson: Victorian plant ecologist and evolutionist. Ashgate, Aldershot, UK.
Egerton, F. N. 2007. A history of the ecological sciences, part 24: Buffon and environmental influences on animals. ESA Bulletin 88:146–159.
Egerton, F. N. 2008. A history of the ecological sciences, part 27: Explorers of natural history in Russia and the North Pacific during the 1700s. ESA Bulletin 89:39–60.
Frías Nuñez, M. 1994. Tras el Dorado vegetal: José Celestino Mutis y la Real Expedición Botánica del Nuevo Reino de Granada (1783–1808). Disputacíon Provincial de Sevilla, Seville, Spain.
Friedmann, H. The history of our knowledge of avian brood parasitism. Centaurus 10:282–304.
George, W. 1970. Louis Antoine de Bougainville (1729–1811). Dictionary of Scientific Biography 2:342–343.
Glick, T. F., and D. M. Quinlan. 1975. Félix de Azara: the myth of the isolated genius in Spanish science. Journal of the History of Biology 8:67–83.
Goetzmann, W. H. 1986. New lands, new men: America and the second great age of discovery. Viking, New York, New York, USA.
Goodman, E. J. 1972. The explorers of South America. Macmillan, New York, New York, USA.
Griffin, D. R. 1953. Acoustic orientation in the oil bird *Steatornis*. Proceedings of the National Academy

of Sciences (USA) 39:884–893.
Grisebach, A. 1872. Pflanzengeographie und Botanik. Volume 3, pages 232–268 *in* K. Bruhns, editor. Alexander von Humboldt: eine wissenshaftliche Biographie. F. A. Brockhaus, Leipzig, Germany.
Guerra, F. 1970. Félix de Azara (1742–1821), mathematics, geography, natural history. Dictionary of Scientific Biography 1:351–352.
Hahn, R. 1970. Dominique François Jean Arago (1786–1853), physics, astronomy. Dictionary of Scientific Biography 1:200–203.
Hartshorne, R. 1958. The concept of geography as a science of space, from Kant and Humboldt to Hettner. Annals of the Association of American Geographers 48:97–108.
Hein, W.-H. 1959. Alexander von Humboldt und Carl Ludwig Wildenow. Pharmazeutische Zeitung 104:467–472.
Hein, W.-H., editor. 1987. Alexander von Humboldt: life and work. C. Cummings, translator. German edition, 1985. C. H. Boehringer Sohn, Ingelheim am Rhein, Germany.
Helferich, G. 2004. Humboldt's cosmos: Alexander von Humboldt and the Latin American journey that changed the way we see the world. Gotham Books, New York, New York, USA.
Hoare, M. E. 1972. (Johann) Georg Adam Forster (1754–94). Dictionary of Scientific Biography 3:75–76.
Hofsten, N. von. 1916. Zur älteren Geschichte des Diskontinuitätsproblems in der Biogeographie. Zoologische Annalen 7:197–353.
Honigsbaum, M. 2001. The fever trail: in search of the cure for malaria. Macmillan, London, UK.
Hossard, N. 2001. Aimé Bonpland, 1773–1858, médicin, naturaliste en Amérique du Sud, à l'ombre des arbres. L'Harmattan, Paris, France.
Humboldt, F. W. H. A. von. 1793. Florae Fribergensis specimen plantas cryptogamicas praesertim subterraneas exhibens. Henr. Augustum Rottmann, Berlin, Germany.
Humboldt, F. W. H. A. von. 1806. Versuche über die elektrischen Fische. Gilberts Ann. Physik 22:1–13.
Humboldt, F. W. H. A. von. 1816. On the laws observed in the distribution of vegetable forms. (Tilloch's) Philosophical Magazine 47:446–453.
Humboldt, F. W. H. A. von. 1816–26. De instituto operas et de distributione geographica plantarum secundum coeli temperiem et altitudinem montium prolegomena. Volume 1, pages iii–xlvi *in* Nova genera et species plantarum quas in peregrinatione orbis novi collegerunt, descripserunt, partim adumbreverunt. By F. W. H. A. von Humboldt, A. J. A. Bonpland, and C. S. Kunth. Seven volumes. Librairie Gracque-Latine-Allemande, Paris, France.
Humboldt, F. W. H. A. von. 1817*a*. Sur les lignes isothermes et de la distribution de la chaleur sur le globe. Mémoires de physique et de chimie, de la Société d'Arcueil 3:462–602.
Humboldt, F. W. H. A. von. 1817*b*.Geographica plantarum secundum coeli temperiem et altitudinem montium, prolegomena. Libraria Graeco-Latino-Germanica, Paris, France.
Humboldt, F. W. H. A. von. 1818–29. Personal narrative of travels to the equinoctial regions of the New Continent, during the years 1799–1804 by Alexander de Humboldt and Aimé Bonpland. H. M. Williams, translator. Seven volumes. Longman, Rees, Orme, Brown, and Green, London, UK.
Humboldt, F. W. H. A. von. 1819. Sur les gymnotes et autres poisons électriques. Annals de Chimie et de Physiques 11:408–437.
Humboldt, F. W. H. A. von. 1820. Sur les lois que l'on observe dans la distribution des formes végétales. Dictionnaire des sciences naturelles 18:422–436.
Humboldt, F. W. H. A. von. 1820–1821. On isothermal lines and the distribution of heat over the globe.

Edinburgh Philosophical Journal 3:1–20, 256–274, 4:23–37, 262–281, 5:28–39. Reprinted in Egerton 1977.

Humboldt, F. W. H. A. von. 1822. New enquiries into the laws which are observed in the distribution of vegetable forms. Edinburgh Philosophical Journal 6:273–289.

Humboldt, F. W. H. A. von. 1829. On the flight of the condor. Edinburgh New Philosophical Journal 8:142–143.

Humboldt, F. W. H. A. von. 1833. The travels and researches. W. MacGillivray, condenser. J. and J. Harper, New York, New York, USA.

Humboldt, F. W. H. A. von. 1837. On two attempts to ascend Chimborazo. M. Barry, translator. Edinburgh New Philosophical Journal 23:291–311.

Humboldt, F. W. H. A. von. 1849. Aspects of nature, in different lands and different climates; with scientific elucidations. E. J. Sabine, translator. John Murray, London, UK.

Humboldt, F. W. H. A. von. 1850. Views of nature: or contemplations on the sublime phenomena of creation; with scientific illustrations. E. C. Otté and H. G. Bohn, translators. Henry G. Bohn, London, UK.

Humboldt, F. W. H. A. von. 1874. Cosmos: a sketch of a physical description of the universe. E. C. Otté, translator. Four volumes. Harper and Brothers, New York, New York, USA.

Humboldt, F. W. H. A. von. 1989. Schriften zur Geographie der Pflanzen. H. Beck, editor. Wissenschaftliche Buchgesellschaft, Darmstadt, Germany.

Humboldt, F. W. H. A. von. 1993. Briefe aus Amerika. U. Moheit, editor. Akademie Verlag, Berlin, Germany.

Humboldt, F. W. H. A. von, and A. J. A. Bonpland. 1807. Essai sur la géographie des plantes, accompagné d'un tableau physique des regions équinoxiales, fondé sur des measures executes. Fr. Schoell, Paris, France. Partly translated into English *in* Lomolino et al. (2004:49–57).

Humboldt, F. W. H. A. von, and A. J. A. Bonpland. 1811–1833. Recueil d'observations de zoologie et d'anatomie compare faites dan l'Ocean Atlantique, dans l'intérier du Nouveau Continent et dans la Mer du Sud, pendant les années 1799–1803. Two volumes. F. Schoell, G. Dufour, J. Smith, et Gide, Paris, France.

Humboldt, F. W. H. A. von, and A. J. A. Bonpland. 1816–1823. Monographie des Melastomacées. Gide fils, Paris, France.

Humboldt, F. W. H. A. von, A. J. A. Bonpland, and C. S. Knuth. 1819–1824. Monographie des mimoses et autres plants légumineuses du Nouveau Continent. Paris, France.

Jacques, M., S. Provost, A. Turner and G. Azoulay 2003. Des outils pour les sciences. Pages 109–117 *in* Humboldt et Bonpland, 1799–1804: une aventure savante aux Ameriques. Special issue of Musée des Arts et Métiers—La Revue, numbers 39–40.

Jahn, I. 1965. The influence of Alexander von Humboldt on young biologists and biological thinking during the 19th century. Actes du XI[e] Congress international d'Histoire des Sciences 5:81–86.

Jahn, I. 1969. Dem Leben auf der Spur: Die biologischen Forschungen Alexander von Humboldt. Urania-Verlag, Leipzig, Germany.

Jahn, I. 1971. Christian Gottfried Ehrenberg (1795–1876), biology, micropaleontology. Dictionary of Scientific Biography 4:288–292.

James, P. E., and G. J. Martin. 1981. All possible worlds: a history of geographical ideas. Edition 2. John Wiley and Sons, New York, New York, USA.

Jouanin, C. 2003. Les oiseaux du "courant de Humboldt." Pages 32–37 *in* Humboldt et Bonpland, 1799–1804: une aventure savante aux Amériques. Special issue of Musée des Arts et Métiers—La

Revue, numbers 39–40.

Kellner, L. 1963. Alexander von Humboldt. Oxford University Press, London, UK.

Keynes, R. D., and H. Martins-Ferreira. Membrane potentials in the electroplates of the electric eel. Journal of Physiology 19:315–351.

Kish, G. 1978. A source book in geography. Harvard University Press, Cambridge, Massachusetts, USA.

Körber, H.-G. 1959. Über Alexander von Humboldts Arbeiten zur Meteorologie und Klimatologie. Pages 289–335 *in* Alexander von Humboldt 14.9.1769-6.5.1859: Gedenkschrift zur 100. Wiederkehr seines Todestages. Alexander von Humboldt- Kommission der Deutschen Akademie der Wissenschaften zu Berlin, editor. Akademie-Verlag, Berlin, Germany.

Kuhn, T. 1970. The structure of scientific revolutions. Edition 2. University of Chicago Press, Chicago, Illinois, USA.

Kümmel, W. F. 1987. Alexander von Humboldt and medicine. Pages 195–210 *in* W.-H. Hein, editor. Alexander von Humboldt: life and work. C. H. Boehringer Sohn, Ingelheim am Rhein, Germany.

Lange, F. G. 1959. Bildnisse Alexander von Humboldts. Pages 445–458 + 23 plates *in* Alexander von Humboldt 14.9.1769-6.5.1859: Gedenkschrift zur 100. Wiederkehr seines Todestages. Alexander von Humboldt-Kommission der Deutschen Akademie der Wissenschaften zu Berlin, editor. Akademie-Verlag, Berlin, Germany.

Larson, J. 1986. Not without a plan: geography and natural history in the late eighteenth-century. Journal of the History of Biology 19:447–488.

Laudan, R. 1987. From mineralogy to geology: the foundations of a science, 1650–1830. University of Chicago Press, Chicago, Illinois, USA.

Lenoir, T. 1981. The Göttingen school and the development of transcendental naturphilosophie in the romantic era. Studies in History of Biology 5:111–205.

Lenz, W. 1980. The Forsters' offenses against convention during and after Capt. Cook's second voyage around the world and the government reprisals. Pages 682–689 *in* M. Sears and D. Merriman, editors. 1980. Oceanography: the past. Springer-Verlag, New York, New York, USA.

Limoges, C. 1980. The development of the Muséum d'Histoire Naturelle of Paris, *c*. 1808–1914. Pages 211–240 *in* The organization of science and technology in France, 1808–1914. Maison des Sciences de l'Homme, Paris, France.

Löwenberg, J. 1872. Alexander von Humboldt: bibliographische Uebersicht seiner Werke, Schriften und zerstreuten Abhandlungen. Volume 2, pages 487–552 *in* K. Bruhns, editor. Alexander von Humboldt: eine wissenschaftliche Biographie. F. A. Brockhaus, Leipzig, Germany.

Löwenberg, J. 1873. Alexander von Humboldt: youth and early manhood, travels in America and Asia. Volume 1, pages 3–390 *in* K. Bruhns, editor. Life of Alexander von Humboldt. Two volumes. Longmans, Green, London, UK.

Lomolino, M. V., D. F. Sax, and J. H. Brown, editors. 2004. Foundations of biogeography: classic papers with commentaries. University of Chicago Press, Chicago, Illinois, USA.

Lourteig, A. 2003. À la mémoire d'Aimé Bonpland. Pages 48–53 *in* Humboldt et Bonpland, 1799–1804. Special issue of Musée des Arts et Métiers--La Revue, numbers 39–40.

Matagne, P. 1999. Aux origins de l'écologie: les naturalists en France de 1800 à 1914. Éditions du CTHS, Paris, France.

McIntyre, L. September 1985. Humboldt's way: pioneer of modern geography. National Geographic 168, number 3:318–351.

McKinney, H. L. 1972. Wallace and natural selection. Yale University Press, New Haven, Connecticut,

USA.
Meyer-Abich, A. 1969*a*. The philosophy of nature in Alexander von Humboldt's "View of Nature." Acta Biotheoretica 18:9–50.
Meyer-Abich, A. 1969*b*. Alexander von Humboldt as a biologist. Pages 179–196 *in* Pfeiffer, H., editor. Alexander von Humboldt: Werk und Weltgeltung. R. Piper, Munich, Germany.
Minguet, C. 1997. Alexandre de Humboldt: historien et géographe de l'Amérique espagnole, 1799–1804. Edition 2. L'Harmattan, Paris, France.
Murphy, R. C. 1936. Oceanic birds of South America. Macmillan, New York, New York, USA.
Nelkin, H. 1980. Alexander von Humboldt: his portraits and their artists; a documentary iconography. German edition, 1980. Dietrich Reimer, Berlin, Germany.
Nicolson, M. 1987. Alexander von Humboldt, Humboldtian science and the origins of the study of vegetation. History of Science 25:167–194.
Nicolson, M. 1990. Alexander von Humboldt and the geography of vegetation. Pages 169–185 *in* A. Cunningham and N. Jardine, editors. Romanticism and the sciences. Cambridge University Press, Cambridge, UK.
Nicolson, M. 1996. Humboldtian plant geography after Humboldt: the link to ecology. British Journal for the History of Science 29:289–310.
Oppitz, U.-D. 1969. Der Name der Brüder Humboldt in aller Welt. Pages 277–429 *in* H. Pfeiffer, editor. 1969. Alexander von Humboldt: Werk und Weltgeltung. R. Piper, Munich, Germany.
Pabst, A. 1975. Gustav Rose (1798–1873), mineralogy, crystallography. Dictionary of Scientific Biography 11:539–540.
Pennell, F. W. 1945. Historical sketch. Pages 35–48 *in* F. Verdoorn, editor. Plants and plant science in Latin America. Chronica Botanica, Waltham, Massachusetts, USA.
Pfeiffer, H., editor. 1969. Alexander von Humboldt: Werk und Weltgeltung. R. Piper, Munich, Germany.
Richardson, P. L. 1980. The Benjamin Franklin and Timothy Folger charts of the Gulf Stream. Pages 703–717 *in* M. Sears and D. Merriman, editors. Oceanography: the past. Springer-Verlag, New York, New York, USA.
Robinson, A. H., and H. M. Wallis. 1967. Humboldt's map of isothermal lines: a milestone in thematic cartography. Cartographic Journal 5:119–123.
Rodolico, F. 1968. Per la storia della fitogeografia: lettere di Alessandro von Humboldt a Filippo Parlatore. Physis 10:113–118.
Royal Society of London. 1869. Catalogue of scientific papers (1800–1863). Volume 3. George Edward Eyre and William Spottiswoode, London, UK.
Rupke, N. A. 1996. Humboldtian medicine. Medical History 40:293–310.
Rupke, N. A. 2000. Alexander von Humboldt, 1769–1859, German naturalist and traveler. Pages 356–359 *in* A. Hessenbruch, editor. Reader's guide to the history of science. Fitzroy Dearborn, London, UK.
Rupke, N. A. 2005. Alexander von Humboldt: a metabiography. Peter Lang, Frankfurt am Main, Germany.
Sachs, A. 2006. The Humboldt current: nineteenth-century exploration and the roots of American environmentalism. Viking, New York, New York, USA.
Sarton, G. 1943. Aimé Bonpland. [Reprinted without illustrations in Stearn (1968).] Isis 34:385–399.
Schellhas, W. 1959. Alexander von Humboldt und Freiberg in Sachsen. Pages 337–422 *in* Alexander von Humboldt 14.9.1769-6.5.1859: Gedenkschrift zur 100. Wiederkehr seines Todestages. Alexander von

Humboldt-Kommission der Deutschen Akademie der Wissenschaften zu Berlin, editor. Akademie-Verlag, Berlin, Germany.

Schoenwaldt, P. 1969. Alexander von Humboldt und die Vereinigten Staaten von Amerika. Pages 431–482 *in* H. Pfeiffer, editor. 1969. Alexander von Humboldt: Werk und Weltgeltung. R. Piper, Munich, Germany.

Schoenwaldt, P. 1987. Alexander von Humboldt and the USA. Pages 273–282 *in* W.-H. Hein, editor. Alexander von Humboldt: life and work. C. H. Boehringer Sohn, Ingelheim am Rhein, Germany.

Sears, M., and D. Merriman, editors. 1980. Oceanography: the past. Springer-Verlag, New York, New York, USA.

Sellers, C. C. 1980. Mr. Peale's museum: Charles Willson Peale and the first popular museum of natural science and art. Norton, New York, New York, USA.

Sigurdsson, H. 1999. Melting the Earth: the history of ideas on volcanic eruptions. Oxford University Press, Oxford, UK.

Smit, P. 1976. Gottfried Reinhold Treviranus (1776–1837), zootomy, physiology. Dictionary of Scientific Biography 13:460–462.

Snow, D. W. 1961. The natural history of the oilbird, *Steatornis caripensis* in Trinidad, W. I. Part I: General behavior and breeding habits. Zoologica 46:27–49 + 2 plates.

Snow, D. W. 1962. The natural history of the oilbird, *Steatornis caripensis* in Trinidad, W. I. Part II: Population, breeding ecology and food. Zoologica 47:199–221 + 4 plates.

Stafleu, F. A., and R. S. Cowan. 1976–88. Taxonomic literature: a selective guide to botanical publications and collections with dates, commentaries, and types. Edition 2. Seven volumes. Bohn, Scheltema, and Holkema, Utrecht, The Netherlands.

Stearn, W., editor. 1968. Humboldt, Bonpland, Knuth and tropical American botany. J. Cramer, Lehre, Germany.

Stelleanu, A. 1959. Alexander von Humboldt und die Bedeutung seines Wissenschaftlichen Werkes für Hydrobiologie. Pages 423–444 *in* Alexander von Humboldt 14.9.1769-6.5.1859: Gedenkschrift zur 100. Wiederkehr seines Todestages. Alexander von Humboldt-Kommission der Deutschen Akademie der Wissenschaften zu Berlin, editor. Akademie-Verlag, Berlin, Germany.

Tepaske, J. J. 1996. José Celestino Mutis. Pages 703–704 *in* Latin American lives. Macmillan Library Reference, New York, New York, USA.

Théodoridès, J., editor. 1965. Une amitié de savants au siècle dernier: Alexander von Humboldt et Achille Valenciennes (correspondance inedited). Biologie Médicale 54:i–cxxxix.

Théodoridès, J. 1968. Humboldt et Darwin. Actes du XIe Congress International d'Histoire des Sciences 5:87–92.

Théodoridès, J. 1970. Humboldt zoologiste. Episteme 1:99–108.

Théodoridès, J., and M. Destombes. 1969. Sur la presence à Strasbourg d'instruments scientifiques ayant appartenu à A. von Humboldt. Quatre-vingt-douzième Congrès national des Sociétés Savants, Compte Rendus 1:93–98.

Tobien, H. 1974. Alcide Charles Victor Dessalilnes d'Orbigny (1802–57), paleontology. Dictionary of Scientific Biography 10:221–222.

Travers, B. Sept.-Dec. 2003. Bibliographie selective. Pages 136–139 *in* Humboldt et Bonpland, 1799–1804: une aventure savante aux Amériques. Special issue of Musée des Arts et Métiers—La Revue, numbers 39–40.

Treviranus, G. R. 1802–1822. Biologie; oder, Philosophie der Lebenden Natur für Naturforscher und Aertze. Six volumes in three. J. F. Röwer, Göttingen, Germany.

Troll, C. 1969. Die Lebensformen der Pflanzen—A. von Humboldts Ideen in der ökologischen Sicht von heute. Pages 197–246 + 58 photos + 1 diagram *in* H. Pfeiffer, editor. 1969. Alexander von Humboldt: Werk und Weltgeltung. R. Piper, Munich, Germany.

Trystram, F. 1995. Aimé Bonpland (1773–1858) en Argentine. Pages 227–234 *in* Les naturalists français en Amérique du Sud XVI^{e}–XIX^{e} siècles. Yves Laissus, editor. Éditions du CTHS, Paris, France.

Vernet, J. 1978. José Celestino Bruno Mutis y Blossio (1732–1808), botany, astronomy. Dictionary of Scientific Biography 15:429–430.

Verstraete, J. M. 2003. Humboldt océanographe: un visionnair de genie. Pages 22–31 *in* Humboldt et Bonpland, 1799–1804: une aventure savante aux Amériques. Special issue of Musée des Arts et Métiers--La Revue, numbers 39–40.

Von Hagen, V. W. 1945. South America called them; explorations of the great naturalists: La Condamine, Humboldt, Darwin, Spruce. Knopf, New York, New York, USA.

Von Hagen, V. W., editor. 1948. The green world of the naturalists: a treasury of five centuries of natural history in South America. Greenberg, New York, New York, USA.

Walls, L. D. 1995. Seeing new worlds: Henry David Thoreau and nineteenth-century natural sciences. University of Wisconsin Press, Madison, Wisconsin, USA.

Winsor, M. P. 1976. Starfish, jellyfish, and the order of life: issues in nineteenth-century science. Yale University Press, New Haven, Connecticut, USA.

Zimmerman, E. A. W. 1777. Specimen zoologiae geographicae quadrupedum domicilia et migrationes sistens.

Zimmerman, E. A. W. 1778–1783. Geographische Geschichte des Menschen und der vierfüssigen Thiere. Three volumes. Leipzig, Germany.

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Erratum

In the History of the Ecological Sciences, Part 31: Studies of Animal Populations during the 1700s, the conversion on p. 178 should have read, "consisting only of about 40 French arpents [40 arpents = 13–20 ha]."