Humboldt's legacy

Explorer-naturalist Alexander von Humboldt's contributions to the fields of ecology, global change and geoscience fundamentally altered the way we view the natural world and our place in it. On the 250th anniversary of his birth, we look back over his life and compile a collection of articles inspired by his legacy.

On 16 July 1799, Alexander von Humboldt set foot in the city of Cumaná, in what is now Venezuela, having spent the past 41 days sailing across the Atlantic Ocean from Spain on the frigate *Pizarro*. Together with his botanist friend Aimé Bonpland, he would spend the next five years exploring Latin America, characterizing its meteorological and geophysical features, and collecting thousands of botanical and zoological specimens.

Inspired by this cross-disciplinary legacy, we collate a series of recent articles from six *Nature* journals (https://www.nature.com/collections/ceaeaabjia/), organized according to the four major scientific themes of his life: biogeography and mountain biodiversity, interconnected systems and keystone species, land-use and climate change, and volcanoes and geomagnetism.

Humboldt was born into a wealthy Prussian aristocratic family living near Berlin, in present-day Germany, and spent much of his early life exploring the mountains of Europe. His privileged upbringing enabled him to explore a growing obsession with science beyond those borders — and would be an obsession that would eventually lose him all of his inherited wealth in the pursuit of ideas.

Although not the first to formally describe flora and fauna in Latin America (the Spanish botanist José Celestino Mutis had already amassed a huge botanical collection by the time they arrived), what made Humboldt's expedition unique were the comparisons he made to European specimens, and how he linked their distributions to local environmental conditions. These cross-continental comparisons would eventually give birth to the field of biogeography, and Humboldt crystallized them into the world's first ecology book, *Essay on the Geography of Plants*.

Humboldt's vision was that everything in nature was interconnected — a concept that he called 'Naturgemälde', and one that was outlined in a pioneering piece of data visualization in the form of his view of Mount Chimborazo, in Ecuador (Fig. 1). Here, he defined not only the distribution zones of vegetation in relation to conditions such as altitude, temperature and humidity, but crucially also compared these distributions to other mountain ranges of the world — implying a global connection between the biotic and abiotic realms.

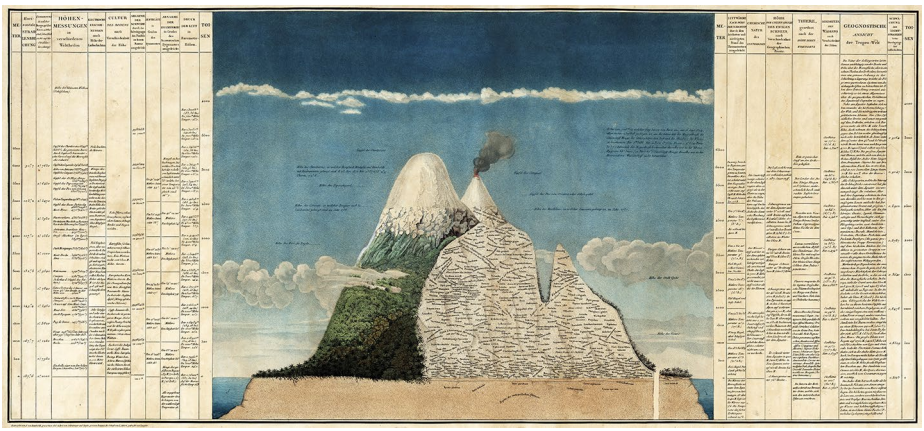

Fig. 1 | Humboldt's view of Mount Chimborazo, Ecuador. First printed in his book, *Essay on the Geography of Plants*, this image is the first depiction of Humboldt's idea of an interconnected web of life, or Naturgemälde, which translates roughly as 'painting of nature'. Different vegetation zones are visualized on the cross-section of the mountain, which can be related to measures of altitude, temperature and humidity via annotations on the left- and right-hand sides. Credit: Science History Images/Alamy Stock Photo

This idea of a holistic web of connections presented a dramatically different vision to the dominant scientific ideas of the time, which focused on organisms at the level of the individual, with humans set apart — ideas influenced largely by Carl Linnaeus. Humboldt anticipated Charles Darwin's famous idea of an entangled bank of connections in the web of life, and also recognized that organisms have a reciprocal effect on their environment — for example, in the shade provided by trees, or the stabilizing effects of vegetation on soil.

This led him to the realization that humans were intricately entangled within this web too. Humboldt recognized that wetland draining and forest clearance by colonists for agricultural production — particularly the production of cash crops for the European and American textile markets — left indelible scars on the landscape, reducing the cover provided by natural vegetation, and leaving the land arid and unproductive. In this respect, he was the first to highlight the effects of human-induced land-use and climate change on the natural world.

Latin America also proved an excellent place to satisfy Humboldt's obsession with volcanoes. Little was known about the formation of volcanic mountains outside of the few active ones in Europe, and in their short trip Humboldt and Bonpland would climb dozens. Taking data on altitude, pressure, geology and magnetic compass bearings, and using measurements that were aided by the technical expertise of Colombian scientist Francisco José de Caldas, they travelled throughout the Andes range. These measurements led Humboldt to discover that the Earth's geomagnetic equator was some 500 miles farther south than its geographic one. Later in life, he established the first coordinated network of geomagnetic monitoring stations across the world, pre-empting the era of big data, international collaborative science and distributed experiments.

Echoes of Humboldt's work and ideas live on in contemporary science. The collection of articles we compile here would have fascinated him, with comparisons of plant diversity across more than 300 mountains (Steinbauer et al.), global-scale comparisons

of polyploid plant distribution (Rice et al.), the delineation of ecoregions among plants and animals (Smith et al.), and a review of the physical influences driving patterns of mountain biodiversity (Antonelli et al.). The interactions governing species coexistence is perhaps even more complex than Humboldt could have envisaged (Mayfield and Stouffer), though common structures are beginning to emerge (Mora et al.). Camara-Leret et al. identify the keystone role played by palm trees, as Humboldt also did while travelling through the grassland plains of Los Llanos in Colombia and Venezuela, while Lu et al. highlight the interconnectedness of climate, hydrology and species.

Peters et al. explore the influence of land use and climate on mountain biodiversity, while Marques et al. show that the increasing trade demand for agricultural products in Western countries is causing land-use driven extinctions of species in the Global South. Alarmingly, Gomes et al. also estimate that 58% of Amazon tree species diversity could be lost in the next 30 years because of these two major drivers. Finally, Humboldt would have been fascinated to learn about the influence of the Altiplano-Puna Magma Body on the history of the Central Andes (Perkins et al.), of the origins and drivers of geomagnetic anomalies at the Equator (Aubert et al.), and of some of the historic insights that can now be gained into the eruptions that helped form the Canary Islands (Paris et al.), whose volcanoes Humboldt first explored during a rest stop on the *Pizarro* voyage.

What else can we take away from Humboldt's legacy? He was fiercely critical of the colonial regimes that allowed him to travel freely throughout Latin America, he disputed the politically loaded term 'New World' and he aimed throughout his life to educate his European readers about the beauty of this part of the world. Throughout his travels, Humboldt often sought and respected the expertise of local indigenous communities, and in his writings argued forcefully that they were no less capable of doing good science than Europeans. Always a strong advocate for the abolition of slavery, later in life he helped pass a law granting freedom to all slaves who set foot in Prussia. He was also a supportive mentor to many young and promising scientists, using his dwindling wealth and influence to help build the careers of, among others, the Swiss palaeontologist Louis Agassiz and the Peruvian geologist Mariano Eduardo de Rivero y Ustáriz.

On his return from Latin America, he communicated his knowledge and ideas in free, open lectures and composed two popular, accessible accounts of his travels and ideas: *Views of Nature* and *Personal Narrative*. These became inspirational travelogues for scientists and artists alike — including a young Charles Darwin, who travelled with copies aboard HMS *Beagle*. Darwin's own voyage was undoubtedly inspired by Humboldt's adventures, and later in life the two met and exchanged letters about their overlapping ideas on the transformation of species.

No other person has had as many species, places or geographic features named after them than Alexander von Humboldt — yet, among these species are those threatened by the very dangers that he identified during his travels, including the critically endangered cactus *Mammillaria humboldtii* and bellflower *Cyanea humboldtiana*[1]. While there is much to celebrate in this anniversary year, it also serves as a sobering reminder of the many global challenges that still persist — particularly in Latin America[2] — some 200 years after he first sounded the alarm on the impact of human-induced land-use and climate change on the natural world. It is imperative that progress on this is accelerated as we approach his tercentenary.

Note: most of these details on Humboldt's life are taken from Andrea Wulf's excellent recent biography[3]. ❐

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