Afterward: Humboldt was Right
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1. Introduction

In 1827 Alexander von Humboldt returned to Berlin on the order of Friedrich Wilhelm III to take up his official position as Chamberlain to the king. He had spent many years in Paris preparing and publishing the great volumes that documented his explorations of the Americas with Aim Bonpland in 1799e1804. The famous lectures that he presented to academics and the public in 1827e1828 marked his arrival and projected the content of the most widely read scientific book in Germany in the 19th century: *Kosmos: Entwurf einer physischen Weltbeschreibung*. In this as in many related works, Humboldt produced the canonical exploration of the relation of sensory perception to global phenomena. What makes Humboldt's perspective especially interesting is that he refused the dichotomies of local and global, qualitative and quantitative, aesthetic and rational, aiming not simply for complementarity but for real integration. That integration depended on two characteristic conceptions, of physiognomy and of instruments. Humboldt borrowed physiognomy from Johann Kaspar Lavater's presentation of the view that character traits were inscribed in the facial features of individuals. The famous illustrations for Lavater's *Physiognomische Fragmente zur Beförderung der Menschenkenntnis und Menschenliebe* were done by Humboldt's drawing instructor, Daniel Chodowiecki, who became director of the Academy of Arts in Berlin. Exemplary in Humboldt's usage are his physiognomic projections of landscapes, as vertical cuts running across broad regions in South America and Mexico. Such a global silhouette, showing mountains, plateaus, temperatures, and "everything that belongs to the structure of the globe," was not merely a physical form but stood "in intimate connection with the advances of the population and with the well-being of the inhabitants."[1] Even more revealing was the "physiognomy of plants," obtained by inscribing characteristic species on the vertical projections and correlating them with elevation, pressure, temperature, rainfall, and other variable parameters. From such pictures Humboldt identified eighteen main forms of plants in different climate zones over the

[1] Alexander von Humboldt, *Essai politique sur le royaume de la Nouvelle-Espagne.* (Paris: Schoell, 1808-14), in Hanno Beck (ed.), *Alexander von Humboldt: Studienausgabe*. 7 vols. (Darmstadt: Wissenschaftliche Buchgesellschaft, 1989-97), vol. 4, 119-120, with plates from Humboldt's *Atlas géographique et physique du royaume de la nouvelle-espagne.* For the perspective here and below see M. Norton Wise, *Aesthetics, Industry, and Science: Hermann von Helmholtz and the Berlin Physical Society* (Chicago: University of Chicago Press, 2018), 176-178.

surface of the earth, from sea level to high mountains and from the tropics to arctic regions.[2] In physiognomy Humboldt aimed to integrate local variation with global structure, in the pictorial mode of a landscape architect or painter. The second means of integration involved the role of instruments, which Humboldt carried with him through the Americas on pack animals. A subsequent example will make the point. When Humboldt arrived back in Berlin he planned to set up a magnetic observatory that would form part of a worldwide network, making standardized observations with precision instruments. In formally announcing his plans, he identified the beginning of the "natural-scientific civilization of the world" with new instruments developed in the seventeenth century. He did not, however, regard these instruments as mere extensions of existing human senses. Instead they were "new organs." As new sensory organs, they provided new means of perception, "new means to set humans (contemplating and knowing) in a more intimate contact with the external world: telescope, thermometer, barometer, pendulum clock, and a tool of more general purpose, the infinitesimal calculus."[3] Humboldt thus made it clear that the new instruments of measurement and analysis were simultaneously new instruments of sensibility. And his conception of instruments melds directly into that of physiognomy, for it was quantitative mapping that revealed the qualitative characteristics of global phenomena. This view of Humboldt's science has been thoroughly developed in recent historical interpretations. Michael Dettelbach emphasizes the inseparability of qualitative and quantitative description. Marie Noelle-Bourget describes the interrelation of humans and instruments in Humboldt's "Republic of Instruments." And John Tresch shows how machines served as mediators between mind and nature while vitiating the antithesis of subjective and objective. In Humboldt's work aesthetic judgment merged with rational analysis.[4]

2. Direct experience

Nearly all of the papers in this volume wrestle with how practitioners of modern science have engaged with the issues that Humboldt sought to address, of whether and how we can experience the global. A constantly recurring question is the meaning of experience, and even more pointedly of "direct" experience. What was "direct"? To many (maybe most) investigators it seems to have meant direct perception via our sensory organs. But that was a contested view. Etienne Benson surveys the attempts in the 1980s of some geomorphologists to renarrate their discipline, extending it to include "mega-geomorphology," which investigated land forms over large regions of the earth's surface using remote-sensing technologies from space. They would renarrate their discipline to make remote sensing an accepted part of what had been a discipline based on direct experience in the field. Among those promoting this "radical" reconception was Robert Sharp, who argued that remote sensing was fieldwork, that it mattered not whether the instruments regularly used by geomorphologists for observations at a distance were carried by hand, by donkey, or by spacecraft.

But what makes this view radical? Humboldt, conceiving instruments as essentially new sensory organs, would have regarded remote sensing as simply a new means of capturing the physiognomy of the globe and a new feature of natural-scientific civilization. Sharp, who regarded himself as a traditional field geologist, was "radical" in the eyes of those for whom fieldwork meant onthe-ground examination of relatively small portions of the earth's surface, coupled with quantitative description and mathematical modeling. Thus, Benson shows us that what counted as "direct experience" and "fieldwork" among most geomorphologists was loaded with disciplinary tradition and territoriality. To open up their identities to new methods of global experience would require reframing the discipline as a whole, which the megageomorphologists attempted with only limited success.

3. The limits of "us"

If the question of what counts as direct sometimes refers immediately to disciplinary identities, it evokes even more generally the view that direct experience is sensory experience and extends no further than the sensory organs of our bodies. It has often been regarded as "embodied experience," as expressed in several papers in this issue. Once again Humboldt's conception of new instruments as new sensory organs flags the problem. Where do "we" end? Are the multiple devices that we employ to supplement our sensations still part of us? For example, does the sensor that I use to detect my heart rate and transmit it to my smart phone, replacingmy finger on an artery, count as providing a direct sensory reading?

Perhaps William Carpenter had something like this conundrum in mind when, as described by Lino Camprubi, he distinguished "mechanical" from "inferential" evidence for deep currents in the Mediterranean. "Mechanical" referred to evidence obtained from the drag on a sail suspended deep in the sea while "inferential" referred to the testimony of comparative temperature and salinity measurements from other regions of the oceans. For Carpenter, as a physiologist who understood the human body in mechanical terms and defended the view that all of our mental functions except volition are those of an automaton, it would have been hard to differentiate conceptually between the mechanical connection of a finger to the artery it (almost)touches and the mechanical connection of that same finger to an undersea sail communicating through hundreds of meters of rope. The term "mechanical" itself, understood as a mechanical linkage, made the evidence "direct," independent of distance to the sail. The term "inferential," however, read as "indirect," depended on somehow breaking this mechanical connection through the body, whether because the measuring instruments lowered in the sea did not sense current or because the judgment involved depended on information assembled from elsewhere. But the inferences, on Carpenter's automaton theory, would have been just as mechanical as the evidence of the sail. This example may help to make clear that the notion of direct sensory experience depends on demarcating a boundary between the sensing body and the environment it senses. This boundary is of course becoming ever more diffuse and permeable as contemporary physiology continues to show how "we" extend into our environment. The explosion of research on the microbiome is a telling example, for it shows the degree to which the colonies of bacteria that inhabit our internal bodies and our external environment are in fact constitutive of us, of our mental states as well as

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[2] Humboldt, Alexander von, *Ideen zu einer Physiognomik der Gewächse* (1806),republished with extensive notes in Humboldt's *Ansichten der Natur* (1808), 3rd ed., 1849; reprint in *Humboldt: Studienausgabe*, vol. 5.

[3] Humboldt, Alexander von, "*Ueber die Mittel: Die Ergründung einiger Phänomene des tellurischen Magnetismus zu erleichtern*," Annalen der Physik, 91 (1829), 319-336, on 319.

[4] Dettelbach, Michael, "The Face of Nature: Precise Measurement, Mapping, andSensibility in the Work of Alexander von Humboldt," Studies in *History and Philosophyof Biological and Biomedical Sciences*, 30 (1999), 473-504. Bourget, Marie-Noëlle, "La république des instruments: Voyage, mesure et science de la nature chezAlexandre de Humboldt," in Etienne Francois, et al. (eds*.), Marianne Germania:Deutsch-Französischer Kulturtransfer im europäischen Kontext* 1789-1914 (Leipzig:Leipzig Universit t Verlag, 1998), 405-36. Tresch, John, *The Romantic Machine:Utopian Science and Technology after Napoleon* (Chicago: University of Chicago Press,2012), ch. 3.

our health and disease. To an increasing degree "we" can be identified and located on a world map by our microbiome, indicating whether we are urban or rural, gardeners or not, living in Africa or the Arctic. In this sense we are constantly and directly experiencing the global world. For we are it. Angela Creager takes up this topic at length in her article on our bodies as chemical sensors, where the issue is the relation between our internal and our external environments. It may be that we do not have direct experience of the chemicals that inhabit our bodies as a result of environmental exposure, in that we may have no conscious sensory experience of them. But the instruments that detect chemicals in our blood and urine and establish their genetic effects provide as exquisitely sensitive a probe of their presence as any other Humboldtian organ of experience. To argue that this is not direct experience of our internal states would seem somehow bizarre. Instead, the highly contested status of such measurements revolves around how directly they can establish the source of contamination, its time frame, and its consequences for health and disease. Who should have oversight and who should bear responsibility have been even more contentious. To explore the history of these issues, as Creager shows, is to unfurl a whole world of regulatory struggles, profits, and justice beneath the question of experiencing the global environment.

4. Distributed cognition and distributed experience

Our thorough embeddedness in our environment has received even broader significance in recent work on "distributed cognition." While cognition has traditionally been located in the brains of individuals, distributed cognition locates it also in our interactions with other people, with artefacts and tools, and with the environment generally. Tools provide the most obvious case, such as the use of a simple calculator to take over functions that our brains previously performed. But of course, as Humboldt would say, such tools are not mere extensions of our senses and mental capacities, they are new organs of cognition, as is apparent in our use of computers for previously unimaginable feats of perceiving and reasoning. But even more interesting are our interdependencies with other people. The classic analysis was given by Edwin Hutchins in a study of the people, skills, and instruments involved in navigating a large ship.[5] A prominent feature is the continual transformation of representations by different actors using different tools and the coordination between them. No individual ever possesses the knowledge embodied in the activities of the team. It is instead distributed through the dynamics of the system and may best be thought of as an emergent property of that system. Some scholars in science studies have adopted this perspective in seeking to interrelate anthropological and philosophical understanding of cognition. One such study suggests a framework for understanding how the visualization of information functions in cognition.[6] Like Hutchins on navigation it stresses representation and interaction as dynamic processes. Importantly, a visual representation performs cognitive functions, which are embodied in it and become part of the cognition of others who make use of it. But different visualizations perform different cognitive functions, which are more or less effective in communication. Even the simplest interaction involving a visualization of information thus becomes a social matter, invoking cultural habits and values that may or may not be shared.

This perspective may be helpful in thinking about what Fa-Ti Fan and Camprubi and Lehmann, in reference to the distribution of sensors over the globe, call "distributed experience." The typical role of such sensors in the environmental sciences is to provide a mapping of data that gives visual access to otherwise invisible patterns (temperature, rainfall, earthquake activity, geomorphology, etc.). A canonical example of such a distribution of experience is Humboldt's 1817 map of isothermal lines: curves of constant annual mean temperature, derived from data acquired from scattered observing stations and mapped over the northern hemisphere for both geographical position and elevation.[7] This mapping was part of Humboldt's attempt to define the distribution of climatic zones over the earth as a critical part of the physiognomy of nature. Proponents of distributed cognition would observe that much of the cognition concerning climate zoneswas embodied in the visual representation itself and was a product of coordination and distribution of local experience over observers, providing a new form of direct global experience. Philipp Lehmann, however, shows how problematic this aim for distributed experience and cognition could become in attempts of the German Colonial Office in the late nineteenth and early twentieth century to establish standardized meteorological recording stations in German East Africa that could produce data suitable for regional mapping and comparative evaluation of agricultural opportunities. Establishing such local consistency turned out to be intractable, partly because of practical problems of instruments and observation but also because standardization itself effaced qualitative judgments and the values associated with them by locally oriented practitioners. They included indigenous people and colonial agents but also some professional meteorologists who prioritized sensory experience and aesthetic judgment over instrument readings.[8] This dichotomizing of qualitative and quantitative values, as Lehmann shows, derailed the global program and any Humboldtian ambitions for integration. Jeremy Vetter similarly problematizes the goal of bridging the gap between local and global knowledge for field scientists at the U.S. Bureau of Biological Survey at about the same time. Following Humboldt, C. H. Merriam and Vernon Bailey sought to integrate local field knowledge into mappings of "life zones" of plants and animals over the country, taking temperature distribution as the most fundamental variable. Their projects, however, ran up against two basic objections: much of the local knowledge of life forms could not be integrated into their global pictures; and temperature alone provided an inadequate basis for identifying life zones. Such tensions between micro-level complexity and macro-level oversimplification seem to be endemic to many of the case studies discussed in this special issue.

5. Concepts and experience

The topics of distributed cognition and distributed experience suggest a related issue that could use more explicit discussion. We experience the world through concepts. Humboldt was very much aware of that when he listed the infinitesimal calculus, along with

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[5] Hutchins, Edwin, *Cognition in the Wild* (Cambridge, MA: MIT Press, 1995).

[6] Liu, Zhicheng, Nancy J. Nersessian, and John T. Stasko, "Distributed Cognition as a Theoretical Framework for Information Visualization," IEEE Transactions on *Visualization and Computer Graphics*, 14 (6), (2008), 1173-1180.

[7] Humboldt, Alexander von, "Des lignes isotherme et de la distribution de la chaleur sur le globe," *Mémoires de physique et de chimie de la Société d' Arcueil*, 3 (1817), 462-602; the chart appeared only in a separate publication with the same title (Paris: Perronneau, 1817); German in Beck, *Humboldt: Studienausgabe*, 6:18-97 (chart on 19).

[8] Interestingly, one of these meteorologists was Karl Wilhelm Dove, grandson of Heinrich Wilhelm Dove, one of Humboldt's main collaborators in Berlin on magnetic observations, who is best known for his own global meteorological mappings. Maull, Otto, "Karl Wilhelm Dove," *Neue Deutsche Biographie*, vol. 4 (Berlin: Duncker & Humblot, 1959), 93.

material instruments like the thermometer, among the “new organs” that set humans in more intimate contact with the world. To employ his friend Joseph Fourier’s differential equation for heat flow to represent and to understand the cooling earth made available an experience quite different from anything the senses alone provided. James Clerk Maxwell, even more explicitly, shared the satisfaction that many physicists found in being able to “feel” the sensory reality of mathematical and quantitative expressions for physical concepts. “They calculate the forces with which the heavenly bodies pull at one another and they feel their own muscles straining with the effort. To such men momentum, energy, mass are not mere abstract expressions of the results of scientific inquiry. They are words of power, which stir their souls like the memories of childhood.”[9] This embodiment of mathematical forms captures rather well the way in which concepts can affect our experience directly, and in a sensory way. If that is true for personal experience of the symbolic expression for momentum (mv), it is even more broadly significant for the distributed experience carried by isothermal lines, magnetic field lines, meteorological maps, and other representations of global phenomena. It may be a serious mistake to separate out conceptual from sensory experience. Certainly that conclusion would follow from the integration of individual minds with their environment as pursued under distributed cognition.

Fa-Ti Fan provides a cogent example of the significance of concepts for experience in his analysis of how Chinese seismologists, reflecting widespread sensibilities of ordinary people during the Cultural Revolution, conceived of an earthquake not simply as a geodynamical rupture but much more broadly as constituted, for example, by the behaviors of domestic and wild animals. It was “an amalgam of myriad micro- and macro-environmental processes and sensory phenomena. It was the total sum of seismicity, chemistry, electromagnetism, sensory experiences, and observable phenomena . a cacophony of light, sound, smell, weather, water, and other environmental changes.” Their research strategies expressed this extensive meaning of the concept of an earthquake. Thus, monitoring animal behavior was monitoring earthquakes themselves, not simply using a biological instrument to detect earthquakes.

Strikingly different is Elena Aronova’s discussion of how animals came to be studied as potential seismic sensors in the US, more as a fortuitous accident than an intimate relation. For two case studies in California she shows that biologists happened to get involved largely because the US Geological Survey was seeking clients for its extensive collection of data from its global network of seismic stations. They offered funds to support innovative projects exploiting their data and they provided a publicity forum for related studies. Biological scientists interested for other reasons in circadian rhythms, on the one hand, and in secretive studies supported by the military of brain waves and operant conditioning, on the other hand, found opportunities to advance their work. At the same time they maintained a critical distance from the Chinese studies, emphasizing the superior quantitative rigor and theoretical foundations of “Western scientific method” in comparison with the more descriptive and mass-based observational accounts emerging from China. Seen in comparative perspective, the articles by Fan and Aronova show how markedly our concept of an earthquake shapes not only what we take to be our experience of it but the way in which research is understood and motivated.

6. Complexity and contingency

These two articles on earthquakes may also be seen to take us back to the problem of prioritizing local or global experience, micro-level complexity or macro-level simplicity. Chinese investigators respected the diversity of local experience while the Americans looked for standardized global variables. Similarly, traditional geomorphologists, with their methodological feet planted literally on the ground, had trouble accepting the remote sensing techniques for revealing global patterns promoted by mega-geomorphologists. The simplified “life zones” of leaders of the US Biological Survey offended nuanced local knowledge. Officials in the German Colonial Office, in their attempt to produce rationalized regional meteorological maps, ran roughshod over qualitative judgments valued in the colonies. Broadly speaking, those seeking global patterns in these cases were pursuing the traditionally dominant aim of scientific explanation, borrowed from physics, of unification and reduction under general principles or laws. Localists have instead stressed diversity and complexity. Historically, this disjunction has often taken the form of the natural sciences versus the human sciences, or the mathematical sciences versus natural historical sciences. And it has often revolved around the idea that lawlike explanation aims to eliminate contingency while descriptive understanding insists on its preservation. So it cannot be surprising to find that investigators in the field sciences have long struggled to find their proper place in a fraught disciplinary terrain.

The question arises, however, of whether these terms of tension are still quite relevant given recent trends in the sciences. Arguably those trends are deemphasizing deductions from laws while models and model systems increasingly occupy the center of investigative practice.[10] That seems to be true not only in the environmental and biological sciences but in the sciences of complexity that have become so prominent in physics and chemistry. Typical problem areas addressed by contemporary investigators include: the folding patterns of various proteins in varying environments; the relation of a particular hurricane to models of globalwarming; and the possible response of a particular individual to a specific drug whose general effects are known only on average for the population at large (personalized medicine). Learning to deal with complexity is perhaps the most pervasive desideratum of contemporary science. And dealing with complexity means dealing with contingency. Today that often involves running dynamic computer models, or simulations, which respond to tiny changes in parameters and to subtle instabilities, yielding results that mimic very local conditions but are not revealed by general laws or even rules. An impressive example is a recent transformation in the very concept of an ordinary snowflake. No longer a universal geometrical structure with six-fold symmetry, its description now requires a whole taxonomy of widely variable forms and subtle structures, each unique, which have been revealed by simulations, some of them previously unknown even in high-resolution photomicrographs.[11] In our contemporary context, where computational strategies like this have become mundane and wheredeven more radicallydartificial intelligence can learn the notoriously intuitive game of GO to defeat a world master, it will no longer suffice to choose either a local or global perspective or even quantitative over

[9] Maxwell, James Clerk, “Address to the Mathematical and Physical Sections of the British Association,” *Report of the British Association for the Advancement of Science*, 40 (1870), 215-229, on 220.
[10] Creager, Angela N.H., Elizabeth Lunbeck, and M. Norton Wise (eds.), *Science without Laws: Model Systems, Cases, and Exemplary Narratives* (Durham, NC: Duke University Press, 2007).
[11] Gravner, Janko, and David Griffeath, “Modeling Snow-Crystal Growth: A Three- Dimensional Mesoscopic Approach,” *Physical Review* E, 79 (2009), 1-18.

qualitative description. Techniques of visualization that interrelate those values have become pervasive. A blossoming interest in the role of narrative in science seems to have a similar basis. So too does the movement in philosophy of science that prefers to focus on understanding rather than explanation.12 All of these developments point to something like an integration of physiognomy with precision instruments. Humboldt was right!

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