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Alpinists and the Terrestrial Limits of Living Beings: an Atypical Contribution to Scientific Knowledge

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Introduction

1 Mountains have historically exerted a strong attraction for the practice of science. However, life science has remained marginal at high altitudes, largely overwhelmed by investment in geophysical, geographic, medical and sociological sciences (Bigg *et al.*, 2009). The recent revival of interest in Alexander von Humboldt[1], inventor of biogeography, scholar and holistic naturalist, is the most notable exception. His attempt to ascend Chimborazo (6,263 m) in 1803, popularized through high quality scientific illustrations, has greatly contributed to this. The same applies to the tutelary figure of Horace-Bénédict de Saussure, inventor of geology and pioneer of mountaineering, despite the rarity of his biological observations in high mountains (Merland, 1988).

2 The first mountaineers (19th century) heavily invested in scientific measures to give legitimacy to their ascents. In doing so, some of them (Edward Whymper in the lead) did more than gleaning legitimacy: they produced notable contributions to knowledge (altitude measurements, rock sampling, ethnographic observations). Recent discoveries on high-altitude biodiversity (Marx *et al.*, 2017) and the emergence of historical ecology applied to high mountains (Wipf *et al.*, 2013) *encourage* a revisiting of the relationship between natural sciences and high mountains, and indeed between natural sciences and mountaineering. This relationship has historically led to “build knowledge” in a singular way: the observation of natural species is a production of facts (Callon and Latour, 1990) that is not carried out by scientists because it is part of an “unattainable”

geography. The objective of this text is thus to trace, through a geohistorical approach, the production of an unsuspected biodiversity at the altitudinal limits of terrestrial life, and to show the fecundity of a socially heteronomous science.

The high mountains and the limits of terrestrial life

3 High mountain is classically defined as the geographical space of landforms extending beyond the upper altitudinal limit of the forest (Chardon, 1984), i.e. about 2,000 m in European mountains up to over 4,000 m in the Himalayas. In the Alps, high mountain includes heaths, alpine grasslands and the nival zone – the latter characterized by permanent snow, glaciers and peaks. If the alpine grasslands define the pastoral space, the nival zone is that of the absence of vegetation. The high mountain which interests us at present is thus the one perceived as a desert, not exploited, at the upper limit of life and whose study requires an atypical mode of movement: alpinism.

4 The high mountain thus considered lies at the margin of the biosphere (Rougerie, 1990). Its environment exerts harsh constraints on organisms: large daily and seasonal thermal amplitudes; frequent freeze/thaw cycles; high intensity of solar radiations; absent or poorly developed soils; low atmospheric pressure. Körner (2011) describes the climatic conditions of high mountains in temperate zones as the environment limit for the physiological functioning of flowering plants – and by extension for a large proportion of living organisms. However, these conditions are also drivers of natural selection, at the origin of an atypical and largely unknown biodiversity (Marx *et al.*, 2017; Dentant, 2018) which is characterized by two notable attributes: (i) a majority of these species are endemic to high mountains, certain mountain regions, or even particular summits[2]; (ii) these species often present remarkable and very particular morphological features, such as the cushion life form, perfectly adapted to high alpine and arctic climates[3].

Alpinism as a physical means of exploration

5 The discovery of this unsuspected biodiversity is not the sole result of a recent investment. Since the founding event of the scientific exploration of the high mountains – the ascent of the Mont Blanc by Saussure in 1787 – some observations of living organisms at high elevations have been made. Saussure thus noted, during his descent from the summit, the presence of Moss Campion (*Silene acaulis* subsp. *bryoides)* (Saussure, 1796), a typical cushion plant, at the site called the “*rocher de l’heureux retour*” (3505 m). This was the first biological observation ever made in high mountains. Humboldt systematically referred to the ascent of Saussure in his physical and biogeographic illustrations of the Andean summits. Humboldt produced a dizzying amount of naturalist and physical data during a trip to Latin America with the botanist Aimé Bonplan, from 1799 to 1804, which enabled him to publish an equally huge amount of scientific works. Some of them, such as the invention of isotherms or the highlighting of altitudinal and latitudinal vegetation zones, have won posterity (Debarbieux, 2012). Saussure and Humboldt were important supporters of field science, which ensures both the production of facts (Latour, 1987) and a sensitive experience of reality guaranteeing a connection to the nature being studied (Livingston, 2003). In the nineteenth century, this approach was truly “sacralized” in countries such as Prussia

and England. Péaud (2014) emphasizes the strong influence of Kantian philosophy on German scientific circles: "seeing [the world] gives us food for thought and thus a system for understanding the world". But the experience of a real space, the impregnation of the terrain cannot be summed up in the visual sense alone: it involves the whole body (Outram, 1996). And the high mountain, as the terrestrial margin of living things, is a space that intensifies the temporality of human bodies (lack of oxygen, continuous muscular effort, constant dehydration). If it is understood that getting to *know each other* involves the psychic and the cognitive, in the high mountains it also requires a whole-body experience.

6 No scientist, after Saussure and Humboldt, will get involved in high altitude in a comparable way. It will be necessary to wait until the birth of mountaineering as a leisure activity for a certain renewal of the exploration of this terrestrial margin. In 1857 the first alpine club was born: the Alpine club of London. Its members were aristocrats and great bourgeois with enough free time to go on "excursions" in European mountains. The majority of them have many other motivations than science to climb them: the fascination, the sublime, the glory, the adventure (Macfarlane, 2003). Socially and culturally not very avowable, these impulses towards the summits have had to drape themselves with legitimacy. Science, especially natural history, was one of the keys to acceptability. Thus John Ball, founding president of the Alpine club, encouraged its members, from the very first edition of the club's magazine, to make scientific observations and measurements: "*Persons not possessing a competent knowledge of any particular branch of natural science cannot expect to contribute much to the existing store of knowledge by such chance observations they may make. To this remark, however, some exceptions may be made, especially in regard to those who attain positions not previously reached by men of science*" (Ball, 1859). Mountaineering could produce facts of science in a geographical space where the bodies of scientists were absent. Thus, what Mao and Bourlon (2017) defined as "adventure tourism with a scientific dimension" was invented.

Dichotomy of science: the field and the laboratory

7 Ball's proposal underlines an essential point: there is a geographical place for scientific observation (the high mountains, which the man of science does not reach) and a geographical place of conceptual exercise of science (the one where the same man of science exercises his function). In certain fields (chemistry or mathematics), the laboratory combines these two places. Within the framework of scientific ecology or geology, there is a strong dichotomy between the field (and its *in situ* observations*)* and the laboratory – a confined space where all the studied parameters are controlled; a space also considered as the place of conceptualization. This dichotomy occupied a central place in the structuring of science at the beginning of the 19th century, with Georges Cuvier as a central personality. Inventor of comparative anatomy, the latter considered the laboratory or study cabinet as the real places of thought and knowledge, stressing that explorations had neither the temporal investment nor the spatial scope sufficient to fully account for reality (Outram, 1996). Conversely, many scholars have seen in field exploration the gateway to their thinking about the world: Saussure, Humboldt, Orbigny, Dolomieu, Wallace and the most famous of all, Darwin. As a young scientist, he circumnavigated the world for five years aboard the *Beagle*. The finches he

observed in the Galapagos will become the most popular illustration of his future theory of the origin of species. Although Darwin did not travel afterwards, his later work owes much to this initial expedition. Many of these exploration trips were thus equated with initiation rites in the academic world, to the point that these same academies issued practical recommendations for expedition reports and the collection of natural specimens.

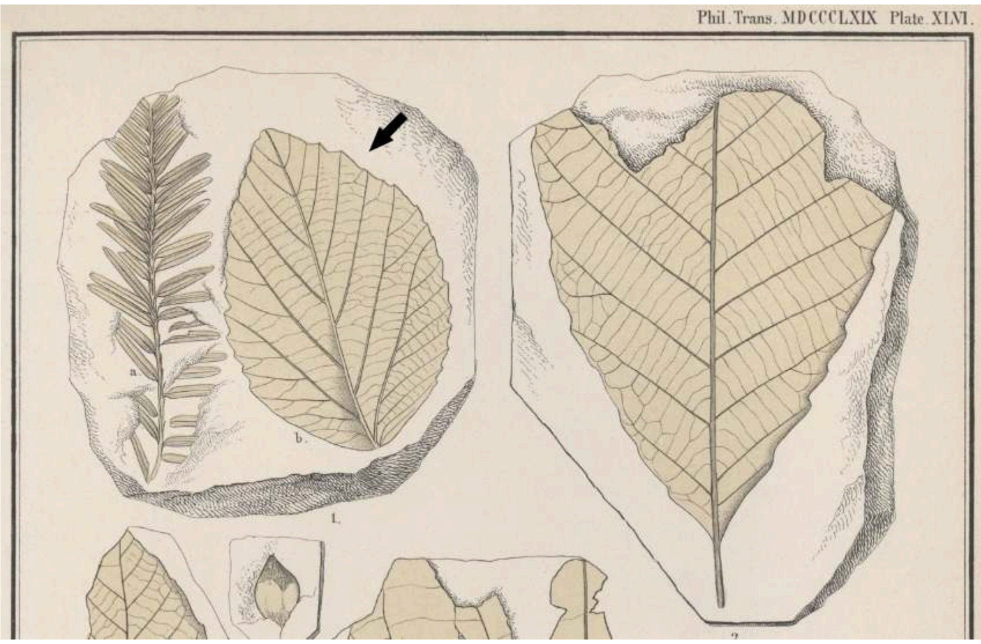
8 When they are not put in duality, field science and laboratory science can pertinently complement each other, as Faugère (2019) recently demonstrated by analyzing the social mechanics of large-scale taxonomic expeditions. Field and laboratory are the two terms of science used by Reichenbach (cited in Hacking, 2004) to define it: the context of discovery and the context of justification. The discovery thus consists of the exploration, the unknown, the locations and the spaces not yet occupied by scientists. It depends on the social, historical and geographical context. The justification is only a question of pure reason, freed from all historicity. It is thus theorization, conceptualization confined to the laboratory. Ball's call thus encourages mountaineers to commit themselves in the context of *discovery.* It does not claim that mountaineers will thus become scientists, but that they will be able, through the commitment of their bodies, to contribute to science, to produce knowledge. Despite a position still deemed heretical for the defenders of a science conducted by "professionals" alone (Lagasnerie, 2011), this network of social groups with complementary skills, producing diverse knowledge (factual or conceptual) on the same non-human organisms – which in turn, by their geographical distribution, shape the mobility of humans – structures a *socio-nature as* formulated by Callon and Latour (1990).

9 Within such a network, Sigrist (2008) proposes a hierarchy of scholars: those in category A (the elite, cited as a reference, rich in publications), those in category B (professionals, but of lesser stature, needy in publications) and finally those in category C (amateurs, collectors, dilettantes). This categorization raises the very question of the definition of a scholar. Having gone from "philosopher of Nature" or "physicist" (18th century) to "savant" and then "scientist" (19th century), he is today's "researcher". Professionalization and *de facto* membership to various universities or academies simplify the social definition of the researcher. But in the 18th and 19th centuries, this professionalization was far from being the norm. And membership to academies was not synonymous with scientific production. These categories thus refer to the field/laboratory dichotomy, no longer from the sole point of view of space, but also from the one of thought: from the 18th century onwards, a philosopher of Nature was the one who *theorized* Nature. He proposed an order to the world by means of his words (Foucault, 1966). Very often, his theories were based on his own experiences, whether in the field or in the laboratory. But the partition of the science promoted by Cuvier gradually imposed itself: since the body's journey was too fragmented, in space as well as in time, it was only the accumulation of samples and observations in laboratories and museums which made it possible to embrace all the objects of knowledge and by extension to make a complete analysis of Nature (Outram, 1996; Livingston, 2003). Theorists ought to sit in venues dedicated to science (academies and museums) and "collectors" ought to explore the field. High mountain environemnts, which largely remained as *terra incognita in* the middle of the 19th century, thus became one of the first terrestrial spaces where this partition of science was exercised. The example of the mountaineer Edward Whymper is enlightening in more than one way.

Edward Whymper: the discovery of extreme biodiversity

10 Edward Whymper was recruited as an engraver, at the age of 20, by the publisher William Longman to illustrate the Alpine club’s journal “*Peaks, Passes and Glaciers*”. His mission was to make engravings of the Alps of Switzerland and Dauphiné – the latter being still almost completely unknown. Whymper will magnificently accomplish his task, and even more revolutionize mountaineering by climbing major summits never reached before. The culmination of his hunger for heights is the first ascent of the Matterhorn (4,478 m), on July 14, 1865. This ascent ended in a drama that became famous (four of the seven climbers perishing on the way down) and gave rise to the first media outburst on what would later be called “the homicidal Alp”[4]. But this ascent also conferred glory to Whymper. While barely 25 years old, he joined the Royal Society, a very elitist club which assured the young man fruitful meetings with eminent scientists of the time: the botanist Joseph Hooker, the anthropologist Francis Galton, the entomologist Henry Bates or the geologist Charles Lyell. After an intuitive and methodless start in science (plant observations on the Lion Ridge, on the Italian side of the Matterhorn), his relations within the Royal Society convinced him to set up a scientific expedition in search of fossils in the Disko Bay, Greenland. He took advice from the scientists of his acquaintance – especially the great entomologist and Amazon explorer Henry Bates – and, like Humboldt, invested in numerous measuring instruments. He also recruited a scientist in charge of carrying out cartographic surveys and organizing herbaria and fossil collections. This recruitment turned out to be a disaster, as the individual, named Brown, proved to be an ambitious jealous of Whymper (Smith, 2011). Whymper, who was criticized for not being a “professional” in science (Brown referring to him as a “simple illustrator”), had enough mental resources to ignore him and build up a remarkable fossil collection on his own. Much to Brown’s chagrin, Whymper himself sent his collection to the most prestigious paleobotanist of the time: Oswald Heer. As a results of his admireration of Whymper’s alpine exploits, Heer dedicated to him a fossil tree from this collection : *Viburnum whymperi* (figure 1).

Figure 1: *Viburnum whymperi*



Viburnum whymperi (black arrow), fossil tree described by Heer from the samples brought back by Whymper from his 1867 expedition .

Source : Heer O., (1869). "Contributions to the fossil flora of North Greenland, being a description of the plants collected by Mr. Edward Whymper during the summer of 1867." *Philosophical Transactions* 159: p. 445-488.

11 At this stage of Whymper's career, two fundamental elements should be emphasized: (i) Whymper, in his alpine ascents, had made opportunistic observations in the spirit of Ball's call. With Disko's expedition of 1867, science clearly became a key objective of his journey. (ii) Through his remarkable collection of fossils, Whymper integrated into this new life course what Sigrist and Vinck (2017) refer to as "intermediate objects": specimens, illustrations or writings that allow the circulation of scientific knowledge, and in many cases, support a theory. For these authors, it is precisely the organization and purpose of these objects that distinguish the researcher from the amateur, in the sense that the idealized researcher does not target the spectacular but the significant, the useful to a heuristic approach, while the amateur constitutes a "cabinet of wonders", intended to be admired and commented on. In the 19th century, the organization of intermediate objects intended for science reached its apogee in Museums, where the arrangement of collections reconfigured Nature in a confined space (Livingston, 2003). Whymper is part of this scientific logic: the realization and destination of his fossil collection – intermediate objects – feeds Heer's research.

12 Building on his recognition by the academic world and his deplorable experience with Brown, Whymper organizes his third major expedition without planning to take any "professional" scientist with him. His objectives remain plural: while he aims more than ever to contribute to scientific knowledge, he also wants to climb the highest peaks ever reached by a human being.

13 Whymper is one of the rare cases in the history of mountaineering to master all types of intermediate object production of the time: exceptional draftsman, talented writer, all he had to do was to gain mastery in the collection and conservation of natural specimens. Relying on his friendship with Bates, he trained himself in the specific

techniques of collecting insects and some other biological groups such as snakes and amphibians. At the end of 1879, he embarks for Ecuador with the famous Valle d'Aosta guide Jean-Antoine Carrel. He has just read with passion the report of the French expedition of La Condamine (one of only two authorized by the King of Spain in 300 years of occupation) to verify Newton's theory that the Earth was flattened at the poles and wider at the equator. The members of the expedition will return to France almost 20 years after their departure and will validate this theory. An outstanding example of field science.

14 Whymper is much more fascinated by La Condamine than by Humboldt. He considers that the latter had not been as high in altitude as he claimed (it has since been widely accepted that Humboldt tended to report events with a certain leeway (Wulf, 2017)). Whymper and his companions harly made the first ascent of Chimborazo (6,263 m) (figure 2), where he highlighted the possibility (and necessity) of acclimatization to high altitude. In the same time, they made the first ascent of the Antisana (5,753 m), a mountain that inspired Humboldt in his work on the zonation of vegetation (Moret *et al.*, 2018).

Figure 2: Chimborazo summit on the first ascent (engraving)

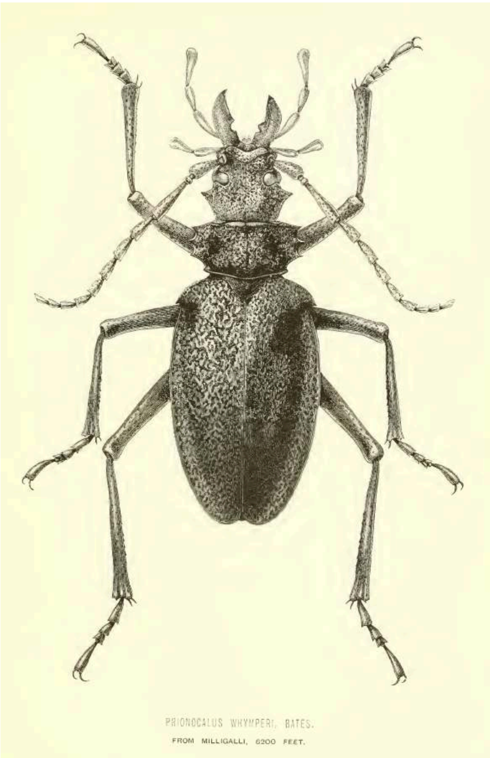
Chimborazo summit on the first ascent. Joseph-Antoine Carrel (foreground) carries a barometer to measure altitude. Engraving by Edward Whymper.

Source : Whymper E., 1891. Travels amongst the great Andes of the Equator, John Murray.

15 From his expedition to Ecuador, Whymper brought back several thousands of insect specimens, mainly collected above 2,500 m. Henry Bates add to hire seven assistants to face the astronomical quantity of samples to be studied. 359 species are thus described in the appendix of his expedition report (Whymper, 1891), an appendix that became famous under the name "Whymper's bug book". Among these species, 131 are new to science, with no less than 14 new genera. These figures are colossal for taxonomic work. Seven taxa were dedicated to Whymper: three beetles (*Heterogomphus whymperi*, *Prionocalus whymperi* (figure 3), *Xenismus whymperi*), an ant (*Holcoponera whymperi*), a bug (*Pnohirmus whymperi*), a snake (*Coronella whimperi*) and a frog (*Hylodes whymperi*). A

scientific consecration for a man who climbed up to the highest altitudes ever reached during his lifetime and brought to light an exceptionnal and unsuspected biodiversity . Taking Humboldt's opposite view of the high mountains, these discoveries made him write: "In his *Vues des Cordillères*, Humboldt deplores the small results which have been attained upon high mountain expeditions in the following passage*: "Ces excursions pénibles, dont les récits excitent généralement l'intérêt du public, n'offrent qu'un très petit nombre de résultats utiles au progrès des sciences"*[5] *[...]* Yet, enough I trust appears to encourage my contemporaries in mountain-travel to continue similar researches, laborious and unthankful though they may be; gradually to amass such a body of evidence as will in course of time render no longer true the dictum of my illustrious predecessor; and will permit it to be said, instead, that high-mountain explorations, although perhaps of little interest to the general public, are of great value to Science" (Whymper, 1891). A call even stronger than Ball's one in 1859, because Whymper now speaks as an expert.

Figure 3: ***Prionocalus whymperi***



Prionocalus whymperi, beetle brought back from the Andes by Whymper. This species new to science was described by Bates and dedicated to Whymper. Engraving by Edward Whymper.

Source : Whymper E., 1891. Travels amongst the great Andes of the Equator, John Murray.

16 Bates benefited from these samples, debating Darwin's view about the causes of species distributions across the American continent. But like Darwin, he missed a key point: if all the species discovered by Whymper above 4,500 m were new to science, it is because high mountains act as a powerful engine for the emergence of new species, through strong natural selection pressures (Rahbek *et al.*, 2019).

17 Beyond the intermediate objects collected or constructed by Whymper, the importance of a privileged relationship with a theorist in order to build knowledge clearly emerges.

Whatever the remarkable merits of Whymper, his scientific contribution took shape thanks to the encouragement, support, and conceptualization brought by Henry Bates – and before him, by Oswald Heer. And the presence of this “mediatingbeing” that is the theorist appears central to the process.

From “intermediate objects” to “mediating beings”.

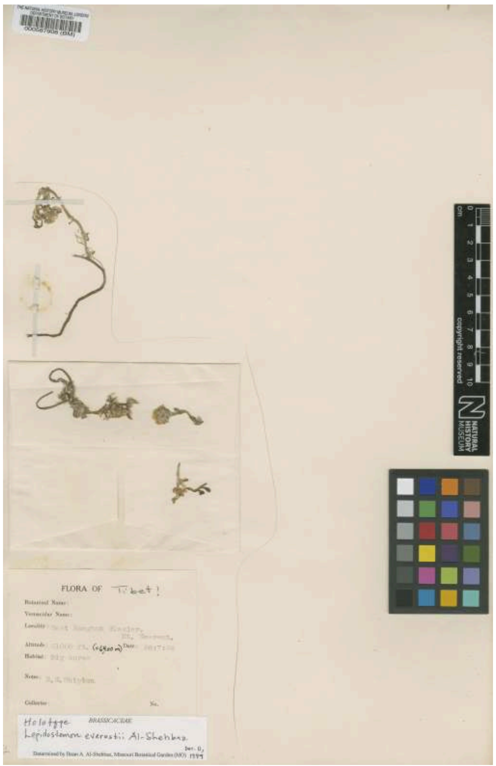
18 Latour (2015) differentiates the status of the intermediary and the mediator (object or living being): the former only transports information when the latter acts by inducing “bifurcation”, that is creating a new understanding, a new apprehension. Latour takes up the concept invested by Serres (1974) and defines the mediator as a translator. The mediator of the nineteenth century is the one who designates the intermediate objects in taxonomy as much as situates them in theoretical knowledge, or to use Foucault’s terms (1966), the theorist, by his mediation, designates and derives the natural specimens in the same impetus.

19 In 1878, in a contemporary era of Whymper’s Ecuadorian expedition, Paul Guillemin, a French mountaineer and naturalist, succeeded the third ascent of La Meije (3,983 m) together with Pierre Gaspard. There he discovered and collected three plant species at 3,600 m of altitude (Dentant and Moine, 2020). At the time, this finding constituted a record for the Alps, moreover on one of its most prestigious peaks. The purple mountain saxifrage (*Saxifraga oppositifolia)*, alpine toadflax (*Linaria alpina)* and alpine forget-me-not (*Eritrichium nanum)* make their (ephemeral) entry into the lexicon of the brand new French Alpine Club. The three specimens, analyzed at the Botanical Society of Lyon, have a high impact on its community. One of its eminent members wrote: “[...] Alpinism, I am convinced, is called upon to extend the field of Natural History and to render immense services to the study of the various branches of this science, and especially to the study of botany” (Carret, 1880). A new era seemed to have begun for science in the high mountains. But in the absence of translation or of mediating beings to make the academic world taking up the question, this surge remained unheard for a long time. The field discovery at high altitude was considered fundamentally “unacademic”. The academic people was then the mediator between the field observations and concepts.

20 Thus, it is not until 1935 that a fresh start occured. After the Alps and the Andes, the highest mountains of the planet were invested (again and again) by the British. The exploration of the highest point of the globe, the Everest, began in 1921. Eric Shipton, adventurer, writer and iconoclastic mountaineer, is like many members of his generation imbued with the writings of Whymper (Shipton, 1969). He modestly tries to follow in the master’s footsteps. In 1931, he in turn became the human being to have been at the highest altitude ever reached, on the summit of Kamet (7,756 m). During this expedition, he discovered a personal attraction for plants that will lead him, four years later, to harvest two plant species at 6,400 m, at the foot of the austere north slope of Everest. Brought back to the British Museum, one of them was quickly identified because it was already known in Tibet: the cottony saussurea (*Saussurea gnaphalodes).* The other plant was unknown, became “buried” and forgotten in the herbarium collections. Like Guillemin, Shipton did not meet in his approach a mediating being able to make his own these exceptional observations. It will be necessary to wait 65 years after the expedition, and 23 years after Shipton’s death, for a

scientist to become interested in the forgotten plant. New for science, it will be named *Lepidostemon everestianus* (Al-Shebhaz, 2000) (figure 4). Its resurrection for science opens perspectives for fundamental research: analyzing its evolutionary origin thanks to its genome in order to understand the mechanisms of natural selection at very high altitudes.

Figure 4: *Lepidostemon everstianus*



Lepidostemon everstianus, a plant brought back from Camp III, at an altitude of 6,400 m on the Tibetan side of Everest (Shipton's herbarium).

Photograph from the British Museum.

Discovering the extreme limits of life

21 The American scientific expedition to Everest in 1963 marked a turning point in this way of producing knowledge. In the era of the Cold War, of Cuba's missile crisis, the justification for climbing unconquered summits took a completely different turn: that of providing the army with concrete elements on the physiological and psychological capacities of individuals in extreme situations (Clements, 2005). The expedition is thus jointly financed by the US Army and the National Geographic Society. The National Geographic Society hires professional climbers to ensure to reach the summit – and thus the mediatic success of the expedition.

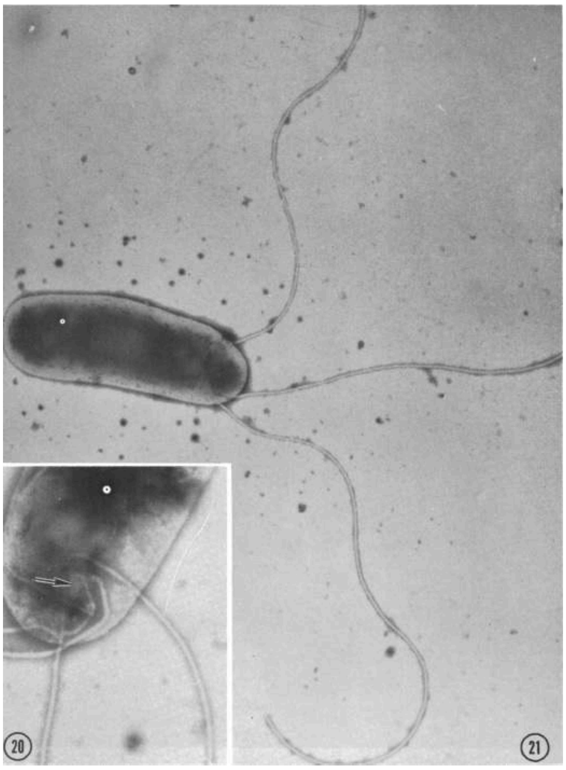
22 Lawrence Swan, a researcher in scientific ecology at San Francisco State University, knows the needs of research at high altitudes. A specialist in spiders, he studied them in 1954 on the slopes of Makalu, at an altitude of over 6,700 m, and knows that frugality in equipment and protocols is the best guarantee of success. The 1963 expedition, which claims to be scientific, does not, however, include a single biologist. Thanks to

his previous work, Swan knows many of the professional mountaineers recruited. He provided three of them with a vial, fitted into a pocket, simply instructing them to collect rocky debris at the highest possible altitude.

23 The scientific part of the expedition turns into a fiasco, even if its members tried to limit its scope (Clements, 2005). The fact that several of them reached the summit all the same, and that the *National Geographic* magazine wrote an attractive account of it, offers an aura of success to the expedition. In this historical period of international tension, American patriotism was flattered by the presence of Americans on the roof of the world for the first time in history. The initial scientific incentives were almost forgotten.

24 Swan was able to recover two vials of debris samples collected at 8,400 m. He pays a vibrant tribute to the two climbers: “Whereas, highly motivated, single purpose climbers are not noted for their cooperation in scientific adventures, two climbers, Lute Jerstad on the West Ridge and Barry Corbet on the South Col approach amazingly filled their vials at 8,400 m” (Swan, 1990). He sent these samples to the NASA laboratory based in Ames (California), where the first astrobiology[6] studies were undertaken. The air contained in the boxes was indeed three times less dense than at sea level, and Swan proposed to analyze them in the same way as if the boxes had just returned from Mars, where atmospheric pressure is ten times lower than at Earth surface. He considered that the terrestrial site with the closest physico-climatic conditions to those of Mars surface is the summit of Everest. The result will be the discovery of new bacteria, with a physiology clearly adapted to daily freeze/thaw cycles and strong light radiation (Swan, 1992). A totally unknown type of bacteria was described in relation to its geographical origin: Geodermatophilus everesti (figure 5). More recently, it has been shown that Geodermatophilus are among the only terrestrial organisms capable of resisting UV intensities ten times higher than those measured on Mars surface. In short, a perfect example of what extraterrestrial life could be. The discovery of these bacteria in 1963 fed what was to become NASA’s Viking program: the sending of robots to the Red Planet to explore its physical conditions and the possible presence of life[7].

Figure 5: *Geodermatophilus everesti*



Photograph of *Geodermatophilus everesti* (x 45,400), bacterium discovered under the summit of Mount Everest and remaining to this day the highest elevated organism ever contacted on Earth (source : Ishiguro et Wolfe (1970), *Journal of Bacteriology* 104(1)).

Source: Ishiguro, E. E., & Wolfe, R. S. (1970). Control of morphogenesis in Geodermatophilus: ultrastructural studies. *Journal of Bacteriology*, *104*(1), 566–580. https://doi.org/10.1128/jb.104.1.566-580.1970

25 For the first time since Carret's declaration in 1880, mountaineering had fully contributed to "extending the domain of Natural History". A researcher like Swan had understood the interest of using mountaineering – and by extension the "bodies" of mountaineers – as a means of producing science.

From the mediating being to the border zone

26 Swan is thus the first mediating being to formalize a specific association with alpinists – and not to help alpinists to valorize intermediate objects collected in their own adventures. Since then, the personalization of the relationship to science has been strongly transformed: from the last quarter of the 20th century onward, new non-academic institutions have emerged, one of whose vocations is the production of naturalist data. The field thus becomes the location of a hybrid culture (Faugère and Mauz, 2013) invested by new experts: rarely theoreticians, these actors bear a type of science that has been partly disinvested by academics who were then focused on new laboratory disciplines such as microbiology, isotopic analysis (geology) or statistical modeling. On the French territory, these new experts correspond to agents of protected areas, botanical conservatories and others. The relationship with research no longer requires a single interpersonal relationship – and therefore a mediating being – but an intermediate zone between academic and non-academic institutions. What Mauz and

Granjou (2013), following Kohler (2002), have defined as a “border zone”. This zone does not cancel the need for interpersonal relationships, but it does imply an institutional – and therefore symbolic – level that was previously absent. It is in this sense that the appearance of this border zone can be seen as a collaborative turning point, even if conserving the partition between field and laboratory actors.

27 At high altitude, this turning point has taken on an even more singular form. Since a *cordée* consists of two individuals linked with a rope, the interpersonal relationship can never be totally diluted in institutions. In order to be roped up, the mediating being, the theorist, has reinvested the field: he (re)integrates fully the context of the discovery, as during the expeditions of Saussure or Humboldt. This is more a return to the very origin of science at high altitude than a turning point or a novelty. But at the other end of the rope, on the other side of the border zone, new figures of scientists emerging from the paradigm of Nature conservation have been involved. Mountaineers are thus no longer just “category C” collectors, but theorists and naturalists co-producers of science (Bourassa *et al.*, 2007). The high mountain thus becomes a socio-nature combining intermediate objects, mediating beings, conservation scientists and border zone. Scientific expertise is not diluted, it is redistributed.

Conclusion

28 The geohistorical analysis of life science in high mountain environments illustrates how the production of scientific facts in their “radical contingency” (Lévi-Strauss, 1962) is dependent on exploratory bodies (mountaineers) as much as on mediating beings (theoreticians). But at the beginning of the 21st century, the original field/laboratory dichotomy is being reconfigured by the modern approach of the “decolonization” of knowledge (Smith, 1999): science is no longer seen as the sole product of the academic world, but becomes a co-production of actors in a border zone between academics and non-academics. This new alliance redistributes expertise: designating species for non-academic actors; deriving facts into theory for academics, when they accept to reconfigure their role into the one of a mediator. It is therefore not so much a question of heteronomy or autonomy of science, but of hybridization between actors of science, which leads to results as promising as the description and redefinition of biodiversity at the limits of life (Boucher *et al.*, 2021).

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NOTES

1. Mainly due to the excellent work of Andrea Wulf (2017)
2. As an example: the highest plant of the Andes Cordillera, *Parodiodoxa chionophila,* discovered at 5,800 m in Nevado de Cachi (Argentina), is currently only known from about ten localities.
3. This is the case of the androsace of Viso (*Androsace vesulensis*), an endemic cushion species of the eponymous summit.
4. Expression popularized by the novelist Paul Hervieu in an eponymous work of 1886.
5. "These painful excursions, whose stories generally excite the interest of the public, offer only a very small number of results useful to the progress of science"
6. Study of conditions conducive to life on exoplanets.
7. The 2021 NASA *Perseverance* expedition shows the still current vitality of this research.

ABSTRACTS

High mountain environments have long been considered to be devoid of life. If science has been a relevant means of legitimization and narrative from the very first explorations of high altitudes, life sciences (biology, ecology) have occupied only a marginal place. Even the inventor of biogeography, Alexander von Humboldt, saw little interest in studying these margins of the biosphere. However, the pioneers of alpinism have approached these *terra incognita* beyond the sole prism of the geographical unknown. Personalities such as Edward Whymper perceived that the involvement of their bodies in these extreme environments could be a powerful means of producing knowledge, through the collection of unsuspected living organisms, and by extension to become contributors to science. Professional scientists had to take hold of these intermediate objects, and make themselves mediators between the field and theory; they had to become « mediating beings ». Until the emergence of a new scientific assemblage, involving new actors from conservation biology. Mountaineers have thus mutated from collector bodies to co-producers of science.

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Keywords: alpinism, life science, high mountain, intermediate objects, mediating beings

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