The Physiology of Extremes: Ancel Keys and the International High Altitude Expedition of 1935

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SUMMARY: This article examines the International High Altitude Expedition of 1935 and its significance in the life and science of Ancel Keys. Both the expedition and Keys's story afford excellent opportunities to explore the growing reach of interwar physiology into extreme climates—whether built or natural. As IHAE scientists assessed human performance and adaptation to hypoxia, low barometric pressure, and cold, they not only illuminated the physiological and psychological processes of high altitude acclimatization, but they also drew borderlines between the normal and the pathological, paved the way for the neocolonial exploitation of natural and human resources in Latin America, and pioneered field methods in physiology that were adapted and adopted by the Allied Forces during the Second World War. This case study in the physiology of place reveals the power and persistence of environmental determinism within biomedicine well into the twentieth century.

KEYWORDS: Ancel Keys, climate, physiology, Andes, acclimatization, fatigue, field studies, human biology

Until 2009, the record for the world's highest arterial blood draw was held by physiologist Ancel Keys. The blood was taken from Keys's arm in June 1935, at 20,140 feet, just shy of the summit of the Chilean volcano Cerro Aucanquilcha.[1] Keys emerged from his ice cave dwelling for this purpose

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1. Michael Grocott, Daniel Martin, Denny Levett, Roger McMorrow, Jeremy Windsor, and Hugh Montgomery, "Arterial Blood Gases and Oxygen Content in Climbers on Mount Everest," *New Engl. J. Med.* 360 (January 8, 2009): 140–49. See David Bruce Dill, *Life, Heat, and Altitude: Physiological Effects of Hot Climates and Great Heights* (Cambridge, Mass.: Harvard University Press, 1938), 148–49.

and for another member of the International High Altitude Expedition (IHAE) to record the act on Technicolor film.[2] For a total of six days and seven nights, Keys had lived in the cavern with British neurophysiologist and mountaineer Bryan Matthews, whose skills in playing the harmonica had proved as valuable as his scientific ones in keeping the two occupied in their icy, hypoxic cell. Harvard Fatigue Laboratory and Massachusetts General Hospital physician John Talbott, later the editor of the *Journal of the American Medical Association*, drew the blood and, having secured his vial of crimson, rushed the sample down to the group's field laboratory, set up in a mining camp administration building at 17,500 feet. There other members of the scientific team employed a sophisticated array of equipment to determine blood pH and levels of oxygen, carbon dioxide, and lactic acid—to help them learn how Keys's body was adjusting to life at extreme altitude.[3] The work of these men was part of an ambitious research program in "human biology" that was based at the Harvard Fatigue Laboratory (HFL), under the direction of biochemist, physiologist, and social philosopher L. J. Henderson. The manager of the expedition was Ancel Keys.[4]

This article is part of a larger biographical study of physiologist and epidemiologist Ancel Keys (1904–2004), who is best known as the developer of the World War II "K-ration" and a stalwart champion of the diet-heart hypothesis in cardiovascular disease.[5] While high altitude physiology may seem a world apart from the fields of human nutrition and chronic disease epidemiology, I argue that the IHAE proved particularly signifi-

2. Keys's maternal uncle was the silent screen star Lon Chaney. Fascinated by his uncle's success in film and intrigued by this relatively new visual media technology, Keys made film records of all of his scientific work from the IHAE onward. A twenty-two-minute film of the IHAE is held at the Ross A. McFarland Collection in Aerospace and Human Factors Engineering, Paul Lawrence Dunbar Library, Wright State University.

3. For a general account of the IHAE, see Ancel B. Keys, "The Physiology of Life at High Altitudes—The International High Altitude Expedition to Chile, 1935," *Sci. Monthly* 43, no. 4 (October 1936): 289–312. High altitude physiologist and historian John B. West examines the expedition briefly in his *High Life: A History of High-Altitude Physiology and Medicine* (New York: Oxford University Press, 1998).

4. For a discussion of the research program of the IHAE, see Keys, "Physiology of Life at High Altitudes" (n. 3). See also A. B. Keys, F. G. Hall, and E. S. Guzman Barron, "The Position of the Oxygen Dissociation Curve of Human Blood at High Altitude," *Amer. J. Physiol.* 115, no. 2 (March 1936): 292–307; F. G. Hall, D. B. Dill, and E. S. Guzman Barron, "Comparative Physiology in High Altitudes," *J. Cell. Comp. Physiol.* 8, no. 3 (August 1936): 301–13; and Keys, "Report of the International High Altitude Expedition" (mimeographed report, Ross A. McFarland Collection in Aerospace and Human Factors Engineering, Paul Lawrence Dunbar Library, Wright State University).

5. See Todd Tucker, *The Great Starvation Experiment* (New York: Free Press, 2006).

cant for Keys and, by extension, for the sciences of respiratory and nutritional physiology, general physiology, and epidemiology. This is because the IHAE offered Keys, who became a leading figure in these fields, an opportunity to develop an interdisciplinary research methodology for investigating complex problems of human health, performance, and longevity in relationship to extreme physical and social environmental stress. World War II offered Keys additional opportunities to refine this approach—which successfully integrated laboratory experiments with studies in the field—in both his research on portable rations for World War II paratroopers (subjected to climatic extremes in the global theater of war) and his investigations of starvation and nutritional rehabilitation at the war's end (extreme malnutrition, among other deprivations). Later, the widely perceived "epidemic" of heart disease at midcentury led Keys to employ a similar lab–field methodology to measure and compare the effects of regional and local diets on cardiovascular health in seven countries.[6] In short, the IHAE served as a template for the rest of Keys's scientific career.

Place—in this specific case, the high Chilean Andes—was an essential element of physiological research during the first half of the twentieth century. If career-minded plant physiologists and field biologists of the 1910s, 1920s, and 1930s were increasingly turning to the values and practices of the experimental laboratory with mixed, often disappointing, results, as Robert Kohler has suggested, this was not necessarily the case for respiratory, exercise, nutritional, metabolic, and industrial physiologists.[7] These life scientists crossed the boundary between lab and field with growing regularity, and in the process they redefined "the field" to include environments such as an industrial workplace, a desert theater of war, a university playing field, and a stratovolcano. The practical applications of these scientists' researches were wide-ranging. In the 1930s and 1940s, for instance, HFL physiologists studying so-called normal men in

6. See Ancel Keys, "War and Military Food Requirements," *Everybody's Health*, April 1942, 4–5, 15; Rohland Isker and Ancel Keys, "The Ration in Combat," *Quartermaster Rev.* 22, no. 1 (July–August 1942): 29–30, 132–34; Walter Porges, *Report No. 1: The Subsistence Research Laboratory, Part 1: History and Organization, Part 2: Ration Research, 1920–1943* (Chicago: Chicago Quartermaster Depot, Public Relations Historical Branch, 1943), 70–96; Ancel Keys and Austin Henschel, "Vitamin Supplementation of U.S. Army Rations in Relation to Fatigue and the Ability to Do Muscular Work," *J. Nutr.* 23 (1942): 259–69; Ancel Keys, Josef Brozek, Austin Henschel, Olaf Mickelsen, and Henry Taylor, *The Biology of Human Starvation* (Minneapolis: University of Minnesota Press, 1950); Ancel Keys, *Seven Countries: A Multivariate Analysis of Death and Coronary Heart Disease* (Cambridge, Mass.: Harvard University Press, 1980).

7. Robert Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002).

each of these natural or man-made climates were offering instruction to corporate leaders, army quartermasters, federal contractors, and athletic directors on how to optimally "acclimatize" their employees, soldiers, and athletes to perform at peak efficiency. HFL scientists helped inaugurate a new era of acclimatization studies—one that explored human adaptation to "unusual stresses, athletic competitions, exposure to strange environments, and war."[8]

One of the chief features of this new style of acclimatization study was its ability to manufacture alien environments. By 1935, physiologists were able to conduct their climatic studies in both the field and the lab. HFL physiologists, for example, could simulate, inside hypobaric and climate-controlled chambers, the naturally occurring conditions of hypoxia, low barometric pressure, and cold that one encountered at high altitude. However, the process of acclimatization took time: weeks, months, even, some claimed, *years*. Keeping research subjects confined in climate-controlled chambers for such lengthy periods was not a realistic option. Thus, scientists (primarily physiologists) embarked on expeditions to mountainous terrain, where nature became their laboratory. Earlier twentieth-century high altitude expeditions had journeyed to such places as Tenerife (1910), Pike's Peak in Colorado (1911), and Cerro de Pasco, Peru (1921–22).[9] In these far-flung places, researchers recorded their own bodies' adjustment to increasing heights over time. Their acts of climatic heroism paralleled those of auto-experimenters inside the laboratory, both having the potential to lend credibility and authenticity to their scientific findings.[10]

8. Steven Horvath and Elizabeth Horvath, *The Harvard Fatigue Laboratory: Its History and Contributions* (Englewood Cliffs, N.J.: Prentice Hall, 1973), ix.

9. On the history of such high altitude expeditions and their importance for respiratory physiology, see West, *High Life* (n. 3) and K. B. Roberts, "The Principle Structures of Physiology: What and Where Are They? The Case of Barcroft's *Architecture*," *Adv. Physiol. Educ.* 19, no. 1 (1998): S6–S17. See also Jorge Lossio, "Life at High Altitudes: Medical Historical Debates (Andean Region, 1890–1960)" (Ph.D. diss., University of Manchester, 2006); Marcos Cueto, "Excellence in Twentieth-Century Biomedical Science," in *Science in Latin America*, ed. Juan José Saldaña (Austin: University of Texas Press, 2006), 231–40; Cueto, "Science under Adversity: Latin American Medical Research and American Private Philanthropy, 1920–1960," *Minerva* 35 (1997): 233–45; Cueto, "Andean Biology in Peru: Scientific Styles on the Periphery," *Isis* 80 (December 1989): 640–58.

10. For a discussion of Enlightenment bodily heroism and its epistemic value for explorer scientists, see Dorinda Outram, "On Being Perseus: New Knowledge, Dislocation, and Enlightenment Exploration," in *Geography and Enlightenment*, ed. David Livingstone and Charles Withers (Chicago: University of Chicago Press, 1999), 281–94. Historians of Victorian and twentieth-century field science also have observed the validating effects of heroism for scientific character and data. See Henrika Kuklick, "Personal Equations: Reflections on the History of Fieldwork, with Special Reference to Social Anthropology,"*Isis* 102 (March

The Chilean Andes—sharp, snowy, and sulfurous—gave Ancel Keys and his team of nine scientists from the universities of Harvard, Duke, Columbia, Copenhagen, Chicago, and Cambridge a "natural laboratory" in which to test the parameters of human performance at altitude and to illuminate the general biochemical, physiological, and behavioral phenomena of vertebrate acclimatization (IHAE test subjects included sea-level and high altitude species for comparative physiological research).[11] In the case of the IHAE, expedition members could also make comparisons between themselves and local populations, whom, some scientists—especially the Peruvian *indigenista* physiologist Carlos Monge—had speculated, were of a different racial type: "Andean Man," developed over generations lived at great heights.[12] Multidisciplinary, even comparative, studies such as the IHAE helped define the interwar field of "human biology," a term coined by Johns Hopkins University biometrician, biologist, and eugenicist Raymond Pearl to refer to an interdisciplinary and synthetic style of studying human beings that encompassed research in physical anthropology, genetics, clinical medicine, physiology, biochemistry, and both organismal and population biology. A central feature of human biology was its focus on the dynamic, ecological relationship between individuals or populations and their environment. Another feature was a concern with distinguishing the normal from the pathological, with an emphasis on characterizing or defining the parameters of normal human performance. Rendering such definitions, of course, constituted an important scientific and political act.

In 1929, Pearl served as the inaugural editor of *Human Biology*, reasoning six years later that "the essential justification of biology is that it has, and should have, as its primary aim to enable man to better understand himself."[13] In establishing the HFL, L. J. Henderson, Pearl's close friend

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2011), 1–33, esp. 12–14. See also Michael Reidy, "From the Oceans to the Mountains: Spatial Science in an Age of Empire," in *Knowing Global Environments: New Historical Perspectives on the Field Sciences*, ed. Jeremy Vetter (New Brunswick, N.J.: Rutgers University Press, 2010), 17–38; Kohler, *Landscapes and Labscapes* (n. 7). On the history of auto-experimentation, see Lawrence K. Altman, *Who Goes First? The Story of Self-Experimentation in Medicine* (New York: Random House, 1987).

11. The term "laboratory of nature" was coined by the eighteenth-century Swiss naturalist and alpinist Horace-Benedict de Saussure in his *Voyages dans les Alpes* (1779). See Charlotte Bigg, David Aubin, and Philipp Felsch, "Introduction: The Laboratory of Nature—Science in the Mountains," *Science in Context* 22, no. 3 (2009): 311–21.

12. See Carlos Monge, *Acclimatization in the Andes: Historical Confirmations of "Climatic Aggression" in the Development of Andean Man* (Baltimore: Johns Hopkins University Press, 1948).

13. Raymond Pearl, "The Aims and Problems of the Department of Biology, and Their Development," Mimeographed report (March 31, 1935), p. 3, Raymond Pearl Archives, American Philosophical Society, Philadelphia. See also Michael A. Little and Ralph M. Garruto, "Raymond Pearl and the Shaping of Human Biology," *Hum. Biol.* 82, no. 1 (2010): 77–102.

and colleague, hoped to achieve the same goal, noting that the lab's purpose was to make progress "toward a generalized scientific description of the experiences of individuals in their environments." Such a description, claimed Henderson, would "be useful to both public and private executives and to legislators."[14] The Fatigue Laboratory's siting at the Harvard Business School ensured that it attracted the attention of not only some of the finest life scientists in the world, but also some of the most important industries.

Indeed, the IHAE was orchestrated to yield data that were important both to a general scientific understanding of human physiology and to the interests of American mining and aviation concerns, which by the 1930s had heavily invested in the extraction of copper and silver from Chilean mines and the expansion of air routes throughout South America.[15] Copper mining in Chile's Atacama Desert, where the IHAE ventured, represented the largest export sector of the Chilean economy, and three companies—all American—dominated the industry.[16] The railroad lines that the expedition scientists took to their Andean destinations had been built by British and American mining concerns. IHAE psychologist Ross McFarland remained in Chile and Peru once his expedition responsibilities were finished, running tests on pilot and passenger altitude acclimatization aboard trans-Andean Pan American–Grace Airways flights, thereby laying the foundation for human factors research in aviation.[17] Thus, much as tropical medicine was a vital part of the modern colonial enterprise—with Europeans' ability to acclimate to "alien" territories of special concern—research in high altitude physiology served the neocolonial economic and political interests of American corporations, as well as those of the international scientific community. If historians have shown

14. [L. J. Henderson?] "The Harvard Fatigue Laboratory," *Harvard Alum. Bull.* 37 (1935): 549–52, quotation on 549. This article was attributed to Henderson by Bruce Dill, although no byline appears with the essay. See D. Bruce Dill, "The Harvard Fatigue Laboratory—It's Development, Contributions, and Demise," *Circ. Res.* 20–21, suppl. 1 (March 1967): 161–70. L. J. Henderson tried to recruit Pearl to Harvard from Johns Hopkins University in 1929.

15. For more on American investments in Chile, particularly in mining and transportation, and American imperialism in Latin America, see Thomas Skidmore, Peter Smith, and James Green, *Modern Latin America*, 7th ed. (New York: Oxford University Press, 2010), 280–82; Brian Loveman, *Chile: The Legacy of Hispanic Capitalism*, 3rd ed. (New York: Oxford University Press, 2001), 162–229; Robert Daley, *An American Saga: Juan Trippe and His Pan Am Empire* (New York: Random House, 1980).

16. See Skidmore et al., *Modern Latin America* (n. 15), 282.

17. See "Air Accidents Laid to Oxygen Want," *New York Times*, June 11, 1937, 25. Psychologist–physiologist Ross McFarland became the coordinator for the Medical Program at Pan-American Airways a few years after the IHAE. See McFarland, *Keeping Fit for Flying: An Analysis of Important Factors Influencing the Health and the Efficiency of Civil Airmen* (New York: Pan American World Airways System, 1943).

a wealth of interest in the “paradigmatic” European colonial science of acclimatization in the tropics, they are only now beginning to explore the “vertical reach” of expeditionary and field science during the late nineteenth and early twentieth centuries, a period when researchers became intrigued by adaptation to new altitudes, as well as latitudes.[18] The story of Ancel Keys and the IHAE suggests that historians of mountain-based expeditionary science, physiology, and neocolonialism have much to say to one another.

Ancel Keys, to use Robert Kohler’s terminology, was a “border crosser,” whether moving between hemispheres, continents, nations, climatic extremes, scientific disciplines, or the spatial and cultural realms of “the laboratory” and “the field.” Kohler argued in *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (2002) that field scientists working within ecology and evolutionary biology took several decades—until the 1950s—to develop a “hybrid culture” that utilized methods in the field that proved sufficiently rigorous to attract the respect of laboratory-based colleagues. Field scientists accomplished this feat, Kohler asserted, by developing new research techniques that did not rely strictly on the material culture or scientific ideals of the laboratory.[19] More recently, Sharon Kingsland has extended the examination of the lab–field border into the mid-twentieth century, revealing how later plant scientists such as Frits Went could embrace the field as their object of study, but build new “ecological laboratories” that might explore certain dimensions of field ecosystems. “The history of field science,” Kingsland maintains, “is not a story of the creation of one form of hybrid culture, but of two, which coexisted in an uncertain relationship,” along the boundary zone.[20] The story of the IHAE represents a transitional chronological case in which a variety of “applied” physiologists created a new hybrid zone to pursue the parameters of normal human functioning.

Indeed, this analysis of the IHAE supports the existence of multiple hybrid cultures. It demonstrates that for some lab-based life scientists, even individuals possessing sophisticated climate-controlled laboratories as early as 1929, conducting research in the field was a necessity: laboratory conditions would not suffice. Ancel Keys did more than engage hybrid

18. See Michael Reidy, “Oceans to the Mountains” (n. 10). Mountains have become a recent focus of historians of science and colonialism. Volume 22, number 3 of *Science in Context* (2009) is devoted entirely to science in the mountain context.

19. Kohler, *Landscapes and Labscapes* (n. 7). Sharon Kingsland, “Frits Went’s Atomic Age Greenhouse: The Changing Labscape of the Lab-Field Border,” *J. Hist. Biol.*, 42 (2009): 289–324.

20. Kingsland, “Frits Went’s Atomic Age Greenhouse” (n. 19), 292.

cultures of lab and field; he helped chart their course. Labeled a "medical Marco Polo" by his successor at the University of Minnesota Laboratory of Physiological Hygiene, Keys ventured forth not as a medieval Venetian traveler to China and central Asia but as an American physiologist to Chile, Japan, Scandinavia, the Soviet Union, and the Mediterranean—taking his laboratory into the field, sending field samples back to his Minnesota laboratory, and simulating field conditions inside his lab—in a career spanning several disciplines across the twentieth century. In doing so, Ancel Keys moved seamlessly back and forth between landscapes and labscapes, exploring distinctive places and building new scientific spaces in his pursuit of the very frontiers of nutritional, physiological, psychological, and epidemiological research.[21] If Keys had been concerned about finding his "place in biology" when he arrived at the HFL in 1933, two years later he had found that place—literally and figuratively—on the summit of Cerro Aucanquilcha.[22]

Ancel Keys—A "Gifted" Child Grows Up

In 1922, Lewis Terman identified Ancel Keys as a young "genius" and selected him for his longitudinal prospective study of intellectually gifted children. Participating in Terman's research program opened a number of doors for Keys and helped guide his intellectual growth, academic opportunities, and career development—which all could be seen as requiring guidance.[23] Teachers' reports, for example, noted that Keys was capable of performing brilliantly when engaged in his studies, but that was often not the case. The young Californian left school four times during his secondary and college years to hold jobs as a lumberjack, a gold miner, a guano harvester, and finally a mechanic on a ship bound for China.[24] Neverthe-

21. Henry Blackburn, "Cardiovascular Disease Epidemiology," in Walter W. Holland, Jørn Olsen, and Charles du V. Florey, eds., *The Development of Modern Epidemiology: Personal Reports from Those Who Were There* (Oxford: Oxford University Press, 2007), 71–92, quotation on 71. See also, Blackburn, "20th-Century "Medical Marco Polos" in the Origins of Preventive Cardiology and Cardiovascular Disease Epidemiology," *Am. J. Cardiology* 109 (March 1, 2012): 756–67.

22. See Ancel Keys's autobiography, *Adventures of a Medical Scientist—Sixty Years of Research in Thirteen Countries* (New York: Crown, 1999). In it, he discusses the concern he felt as he was leaving Joseph Barcroft's physiology laboratory at Cambridge University: "I learned a lot of physiology but not much was accomplished in research. I had not yet found my place in biology" (15).

23. For more on the Terman Study, see Joel Shurkin, *Terman's Kids: The Groundbreaking Study of How the Gifted Grow Up* (Boston: Little, Brown, 1992).

24. See "School Information Blank" (August 6, 1922), Keys file, Terman Study, Department of Psychology, Stanford University.

less, he graduated in just three years from the University of California, Berkeley, majoring in political science and economics.

Keys floundered a bit thereafter, searching for a vocation and taking a managerial post at a Woolworth's store before Terman recommended that he return to his alma mater for additional science courses. In 1927, Keys enrolled in the Berkeley–Scripps Institution of Oceanography (SIO) Ph.D. program in biological oceanography; he was Scripps' first and fastest doctoral graduate, taking less than three years to complete his degree. With several publications in hand from his dissertation, "A Study of the Selective Action of Decreased Salinity and of Asphyxiation on the Pacific Killifish," Keys was poised to accept a position teaching physiology at SIO.[25] Politics, however, intervened.

Scripps was experiencing growing pains of its own, as its director, Thomas Vaughan, attempted to reconfigure the institution's programs in the laboratory and experimental sciences. Vaughan met resistance on the one hand from the Scripps faculty, some of whom were invested in a more natural historical approach to oceanography, and on the other from the affiliated professors at Berkeley, who regarded degrees in biological oceanography as too narrow and not rigorous enough in the physical sciences. Construction of the new physiology laboratories that Keys was to direct at La Jolla was put on hold.[26] Instead, Keys received a National Research Council fellowship. In 1930 he departed for Copenhagen and the laboratory of Nobel laureate physiologist August Krogh.[27]

Keys's dissertation on the adaptive traits of tidal pool fish in response to changes in oxygen and salinity levels was his first piece of research in the "physiology of place." It prompted Krogh, no stranger to physiology in the field, to assign him "the eel problem" (how eels move seamlessly between fresh and salt water). This Keys solved within a year through an examination of eel gill function; his findings were published in the *Journal*

25. See http://sioalumni.ucsd.edu/facts/alumni_facts.php for mention of Keys's Ph.D. program, the fastest on record, obtained in 2.88 years. Ancel B. Keys, "A Study of the Selective Action of Decreased Salinity and of Asphyxiation on the Pacific Killifish Fundulus Parvipinnis" (Ph.D. thesis, University of California, 1930).

26. Ronald Rainger, "Adaptation and the Importance of Local Culture: Creating a Research School at Scripps Institution of Oceanography," *J. Hist. Biol.* 36, no. 3 (2003): 461–500.

27. Krogh, a comparative physiologist, whose research program extended to the study of respiration and metabolism in humans, received the Nobel Prize for his discovery of the mechanism through which the oxygen demands of muscular tissue at work were met: the perfusion of muscle tissue via new capillaries that remained closed at rest. In 1908, he and his wife Marie made their own physiological field study of Eskimos living in Greenland. See August and Marie Krogh, "A Study of the Diet and Metabolism of Eskimos Undertaken in 1908 on an Expedition to Greenland," *Meddelelser om Grønland* 51, no. 1 (1913): 1–52.

of Physiology.[28] In the course of this study, Keys developed into a respiratory physiologist, drawn to the complex problems of acclimatization and adaptation. By 1931, then, Ancel Keys had acquired significant lab and field experience, focusing on adaptive processes occurring in different species in nature and utilizing biometric, physiological, and biochemical techniques within the laboratory. After a year with Krogh, a Rockefeller fellowship allowed Keys to join Joseph Barcroft's laboratory at Cambridge University in England.

Barcroft was one of the world's most prominent figures in general and respiratory physiology, having continued John Scott Haldane's earlier blood gas studies. In 1921–22 he had led the Anglo-American High Altitude Expedition to Cerro de Pasco, Peru. At Barcroft's laboratory Keys met neurophysiologist and mountain climbing enthusiast Bryan Matthews and began to plan his own high altitude expedition.[29] It was also at Barcroft's lab that Keys most probably made his first contacts with the HFL—through HFL–Massachusetts General Hospital physician Arlie Bock, who had accompanied Barcroft to Peru in 1921–22, and through L. J. Henderson, whom Barcroft admired greatly and with whom he maintained regular correspondence.

Barcroft's approach to physiology was similar to that of Henderson and his Harvard colleague Walter B. Cannon, who coined the term "homeostasis" in his studies of the endocrine and autonomic nervous systems. All three considered themselves "Bernardians," which is to say they shared an interest in the integration of the self-regulating physiological processes that allowed organisms to maintain a stable internal environment—what nineteenth-century experimental physiologist Claude Bernard referred to as *milieu intérieur*.[30] Indeed, the body's ability to self-regulate in the face of novel challenges was one of the most important areas of Anglo-American physiological research during the first few decades of the twentieth century.[31] The preservation of a stable internal environment, of course, was also a requirement of successful acclimatization.

28. A. B. Keys and E. N. Willmer, "'Chloride Secreting Cells' in the Gills of Fishes, with Special Reference to the Common Eel," *J. Physiol.* 76, no. 3 (1932): 368–78; J. B. Bateman and A. B. Keys, "Respiration of Isolated Gill Tissue of the Eel," *J. Physiol.* 77, no. 3 (1933): 271–86.

29. John Gray, "Bryan Harold Cabot Matthews," *Biog. Mem. Fell. Roy. Soc.* 35 (March 1990): 265–79.

30. Stephen J. Cross and William R. Albury, "Walter B. Cannon, L.J. Henderson and the Organic Analogy," *Osiris, 2nd Series* 3 (1987): 165–92. Henderson wrote the introduction to the English translation of Bernard's *Introduction to Experimental Medicine*, translated by Herbert Copley Greene, in 1927.

31. Garland Allen, *Life Science in the Twentieth Century* (Cambridge: Cambridge University Press, 1975; repr. 1981), 95–106; Elin Wolfe, A. Clifford Barger, and Saul Benison, *Walter B. Cannon: Science and Society* (Boston: Boston Medical Library in the Countway Library of

For whatever reason, Keys did not successfully acclimate to the cultural environment of England, claiming that he always felt an outsider. He resisted Barcroft's prodigious efforts to make him Cantabrigian faculty (Sir Joseph arranged for a Cambridge Ph.D. to be awarded Keys).[32] When presented with the opportunity to return to the United States to pursue physiological research at Harvard University, where Henderson and Cannon were both working, Keys packed his bags. In 1933, Ancel Keys departed for the "other" Cambridge, accepting a dual post as an instructor in biochemistry at Harvard College and a research associate at the HFL, which surprisingly was based at the Harvard Business School.

The Harvard Fatigue Laboratory

A college of business might seem a strange home for a scientific laboratory. However, David Edsall, dean of both the Harvard Medical School (HMS) and the Harvard School of Public Health (HSPH), believed that studies of fatigue and efficiency would benefit both industrial hygiene at HSPH and industrial engineering at the Engineering School.[33] His enthusiasm was matched by Business School dean Wallace Donham, who wished to place business education on a scientific foundation. Initially, Donham thought that psychology might furnish such a pedagogical base, and to this end he recruited Australian industrial psychologist Elton Mayo to the Business School faculty. However, psychology alone proved "inadequate because of the narrowness of the scientific background and unsafe because human problems in business administration and particularly in the labor field proved to depend in many cases on individual organic problems."[34] At this point, about 1927, Donham's Harvard College classmate Lawrence J. Henderson was enlisted to bring physiology to bear on the problems of industry.[35] The Laura Spelman Rockefeller grant that had made Mayo's recruitment possible was reframed to address "Research on Industrial Hazards," and the HFL, Henderson's brainchild, was born. The Rockefeller Foundation would provide significant fund-

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Medicine, 2000). See also August Krogh, "The Progress of Physiology," *Amer. J. Physiol.* 90, no. 2 (1929): 243–51.

32. Keys, *Adventures of a Medical Scientist* (n. 22), 14–17.

33. For more on physiology at Harvard, see Alejandra C. Laszlo, "Physiology of the Future: Institutional Styles at Columbia and Harvard," in *Physiology in the American Context, 1850–1940*, ed. Gerald Geison (Philadelphia: Lippincott Williams & Wilkins, 1987), 67–96.

34. Dean Wallace B. Donham to President James B. Conant, February 5, 1937, Lawrence J. Henderson Papers, 1914–1941, carton 3, folder 48, "Committee on Industrial Physiology, 1935–37," Historical Collections, Baker Library, Harvard Business School.

35. See Lawrence J. Henderson, "Business Education as Envisaged by the Scientist," *Harvard Business Review* 5, no. 4 (July 1927): 420–23.

ing throughout the HFL's twenty-year history, regarding HFL's research program in human biology as a part of the foundation's efforts to build a "new science of man."[36]

The "first laboratory for the comprehensive study of normal man," the HFL was conceived by L. J. Henderson in the late 1910s and 1920s, while he was working in Arlie Bock's Massachusetts General laboratory on his landmark studies of blood as a self-regulating physico-chemical system. Henderson had been intrigued by the possibility of larger synthetic studies within human biology—ones that examined the biochemistry, physiology, and psychology of *healthy* humans in relationship to different environmental circumstances.[37] Possessing a philosophical and at times visionary temperament, Henderson also was determined not to remain exclusively within the institutional setting of HMS, where he was required to engage in what he viewed as the mundane task of teaching biochemistry to medical students. Henderson sought a university niche that would support his expansive interests in science, sociology, and the history of science.[38]

The new laboratory might have boasted the most unusual location for physiological research at Harvard, but it was by no means alone in its focus on industrial fatigue, either within the university or within the larger disciplines of business administration and physiology. Harvard's preeminence in American physiology during the interwar years, aided greatly by Cannon's presence at the medical school, is well documented. Cannon's protégé Cecil Drinker led the Department of Industrial (and later "Applied") Physiology, one of four different physiology units at HMS.[39] The scientific concept of industrial fatigue was employed by interwar physiologists in both Britain and the United States to extend their

36. See Sarah W. Tracy, "George Draper and American Constitutional Medicine, 1916–1946: Reinventing the Sick Man," *Bull. Hist. Med.* 66 (1992): 53–89; Tracy, "An Evolving Science of Man: The Transformation and Demise of American Constitutional Medicine, 1920–1950," in *Greater Than the Parts: Holism in Biomedicine, 1920–1950*, ed. Christopher Lawrence and George Weisz (Oxford: Oxford University Press, 1998), 161–88; Lily Kay, *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology* (New York: Oxford University Press, 1993).

37. Horvath and Horvath, *Harvard Fatigue Laboratory* (n. 8), ix. See also D. Bruce Dill, "The Harvard Fatigue Laboratory," (n. 14); D. B. Dill, "L.J. Henderson, His Transition from Physical Chemist to Physiologist; His Qualities as a Man," *Physiol.* 20, no. 2 (April 1977): 1–15.

38. Henderson taught the first history of science course at Harvard College, offering it in 1911–12 and regularly thereafter; he began conducting seminars on Vilfredo Pareto in the Harvard Sociology Department in 1932 and initiated a course in "Concrete Sociology" in the same department in 1938.

39. Laszlo, "Physiology of the Future" (n. 33).

discipline's reach into the world of business administration and practical affairs. Under the rubric of "fatigue," physiologists might expand their field's social role, helping to construct a world in which "physiological knowledge of human abilities, limitations, and requirements would be used to guide social policy."[40]

This was Henderson's vision when he spoke before the crowd gathered at the dedication of the new campus for Harvard Business School in 1927, observing that the Industrial Revolution, and the economic and social changes effected by it, had "produced a new environment in which men live. They live a different life. The activities of their muscles, their postures, and their mental processes, all are more or less modified, and nothing or next to nothing is known about these things." The new environments of everyday life and work that accompanied industrialization and urbanization affected human performance, and American business, Henderson asserted, was handicapped until it knew how and to what degree. Fortunately, he added, physiologists were now able to assess the working man to "study simultaneously several activities of a man—the circulation, the breathing, the changes in composition of the blood, and the activity of other organs." An integrated understanding of the normal functioning of "normal men" in novel environments was within reach of the captains of industry, continued Henderson, if American business schools would simply promote the study of "human biology."[41]

By the time Ancel Keys arrived at the HFL in 1933, it had acquired a reputation as the leading American research institute in industrial fatigue.[42] This was not without irony, however, for only a minority of the laboratory's more than four hundred publications specifically concern that topic. Henderson, it seems, had chosen to include the word "fatigue" in the laboratory's name because it would attract the support of industry, while offering researchers a title broad enough to accommodate his wide-ranging interests in the life and social sciences.[43] As a result, HFL also had acquired an international reputation for its research in general physiology, which included human and comparative studies of exercise, respiration, and metabolism. Visiting and resident scientists explored these areas through cutting-edge studies within the disciplines of bio-

40. Richard Gillespie, "Industrial Fatigue and the Discipline of Physiology," in Geison, *Physiology in the American Context,* (n. 33), 237–62, quotation on 252.

41. Henderson, "Business Education" (n. 35), 422–23.

42. Lucien Brouha, Faculty of Medicine, Liège, Belgium, to Dr. Henderson, May 6, 1936, Lawrence J. Henderson Papers, 1914–1941, carton 3, folder 48, "Committee on Industrial Physiology, 1935–37."

43. [Henderson], "Harvard Fatigue Laboratory" (n. 14).

chemistry, physiology, and psychology. By 1935, Henderson's vision of the synthetic research program in human biology had been realized to a great degree, thanks in large part to HFL's research director, David Bruce Dill, who was both a creative, productive exercise and environmental physiologist and a charismatic and efficient laboratory manager.[44] By all accounts, Dill made the Fatigue Laboratory an exciting and dynamic place to do interdisciplinary research, and Henderson's and Mayo's reputations attracted an international cast of eminent researchers—both Krogh and Barcroft paid visits.[45]

Efforts to measure the physiological dimensions of fatigue in typical work settings, however, proved less than satisfactory. In 1934, Henderson was forced to confront the fact that the work of the Fatigue Laboratory had shown

> that the various unmistakably different disagreeable sensations commonly referred to by the word "fatigue" are in fact the accompaniments of a great variety of different physiological conditions which have in common only this, that the physiological equilibrium of the body is somewhere breaking down.[46]

In short, measuring the myriad and *minute* changes taking place simultaneously in the body, as it attempted to restore or maintain its equilibrium, proved challenging.[47] Increasingly, Henderson, Dill, and the resident scientific staff at the laboratory turned to extreme environments to better elicit, record, and quantify physiological and psychological responses. Thus began a series of field studies of human performance in extreme environments within nature and industry—studies that would attract the

44. On Dill's science and character, see Brouha (n. 42) and John T. Reeves, David Bruce Dill, Jr., and Robert F. Grover, "High Cycling: Bruce Dill Exercises Harvard Men at the Leadville Fish Hatchery," in *Attitudes on Altitude: Pioneers of Medical Research in Colorado's High Mountains*, ed. John T. Reeves and Robert F. Grover (Boulder: University of Colorado Press, 2001), 111–36; and Horvath and Horvath, *Harvard Fatigue Laboratory* (n. 8).

45. See Horvath and Horvath, *Harvard Fatigue Laboratory* (n. 8); Carleton Chapman, "The Long Reach of Harvard's Fatigue Laboratory, 1926–1947," *Perspect. Biol. Med.* 34, no. 1 (Autumn 1990): 17–33; Charles Tipton, "Contemporary Exercise Physiology: Fifty Years after the Closure of the Harvard Fatigue Laboratory," *Exerc. Sports Sci. Rev.* 26, no. 1 (January 1998): 315–39; Robin Scheffler, "The Fate of a Progressive Science: The Harvard Fatigue Laboratory, Athletes, the Science of Work, and the Politics of Reform," *Endeavour* (forthcoming), doi:10.1016/j.endeavour.2011.05.007.

46. [Henderson], "Harvard Fatigue Laboratory" (n. 14).

47. See William Hathaway Forbes reporting on Fatigue Lab in Papers of Sterling Dow, War Archivist, Harvard University Archives, UA I 20.946.6, box 1, "Bock." See also Gillespie, "Industrial Fatigue " (n. 40) for more discussion of the difficulty measuring fatigue in the workplace.

attention of the U.S. military forces as they braced for World War II and a theater of war that included desert, tropical, and arctic environments.

In total about twenty physiological field studies were launched from HFL in as many years. In 1929, Bruce Dill led the first: an investigation of altitude acclimatization and exercise performance in Leadville, Colorado, a community where people lived and worked at 10,150 feet. As with all Fatigue Lab field studies, the scientists subjected themselves to the same research protocols they expected their subjects to endure. Dill, for example, was able to demonstrate in himself and his staff a decline in muscular and cardiovascular output at altitude, followed by a gradual improvement as acclimatization occurred.

By 1934, the lab had completed its first federally funded field work, a study of the effects of dry heat on workers building the Hoover Dam.[48] Securing the cooperation of the secretary of the interior as well as the private construction contractors, Dill and his HFL scientists examined the men who lived and worked at the dam's River Camp, where summer temperatures seldom dropped below 110°F (43°C), day or night. He and the Fatigue Lab scientists found that men could work in the extreme heat for a full eight hours only if they were provided with air-conditioned quarters to recuperate during the other sixteen. Likewise, the men were found to cope with the heat by drinking (water), but they failed to replace salt lost in sweat, predisposing them to cramps and heat stroke. Once air-conditioned dormitories were built at a higher elevation and salt tablets were supplied—per recommendation of the HFL scientists—the string of sixteen heat-related deaths came to an end. Similar fatigue field studies took the Harvard group to a steel mill in Youngstown, Ohio, to the Panama Canal, and to the Mississippi River Delta.[49]

Through these field studies, the Harvard group was able to nurture a hybrid culture that prioritized laboratory research with sophisticated equipment oriented toward the whole organism and its ability to acclimate to/function in different extreme environments. Laboratory apparatuses were adapted to meet the particular field demands in a range of natural and manufactured climates. The HFL researchers who ventured into the field with their lab equipment and methods had little trouble garnering the respect of their laboratory- and field-situated colleagues. Such success stands in contrast to the early-twentieth-century plant ecologists and physiologists profiled by Kohler in *Landscapes and Labscapes.* The differ-

48. See Michael Hiltzik, *Colossus: Hoover Dam and the Making of the American Century* (New York: Free Press, 2010), 223–35; Dill, *Life, Heat, and Altitude* (n. 1).

49. For more on the Harvard Fatigue Laboratory staff's field studies, see Horvath and Horvath, *Harvard Fatigue Laboratory* (n. 8), 62–72. See also Dill, *Life, Heat, and Altitude* (n. 1).

ence here may be between "plant physiologists *of* the field" and "general physiologists *in* the field." Between 1927 and 1947, HFL scientists amassed a reputation for meticulous laboratory work done on the most advanced equipment.[50] Indeed, they could simulate many "naturally occurring" conditions inside their lab. They took their reputation, and an understanding of the value of field studies to larger physiological questions (e.g., how one acclimatized to altitude), into the world outside their business school laboratory. And frequently they did so at the behest of American industry and the federal government—entities that valued the application of general physiological knowledge to human performance in specific places.

The steady stream of prominent American and international physiologists and psychologists who visited HFL for collaborative projects helped the Harvard scientists advance their hybridized lab–field culture throughout Europe, Britain, Scandinavia, and South America, further legitimating this style of scientific research. If the HFL is remembered as "a unit of unique structure and design . . . a magnificent anomaly," there is no denying that its methods and perspective translated well to a variety of physiological subdisciplines and problems that would outlive the lab itself.[51] Belgian exercise physiologist Lucien Brouha, sent by his government to physiological laboratories across Europe and the United States prior to founding the Institut supérieur d'éducation physique at Liège, believed that the Fatigue Lab represented "without possible doubt the best laboratory that I know in the world for the study of the physiology of men. Krogh's laboratory in Copenhagen alone may sustain a comparison, but in my opinion the possibilities of the Fatigue Laboratory are more extensive than those of Krogh's laboratory and the spirit of work is better."[52] Brouha's assessment was accurate. The nascent field of "human biology" found few expressions that were as fertile as the science of the short-lived HFL. The interwar and wartime research pursued there made a profound impact on the fields of nutrition, environmental physiology, exercise physiology, human factors research, and epidemiology—through the scientists who trained there, individuals such as Brouha, Bruce Dill, and Ancel Keys.[53]

50. See Chapman, "Long Reach" (n. 45) and Tipton, "Contemporary Exercise Physiology" (n. 45).

51. Chapman, "Long Reach" (n. 45), 17.

52. Brouha (n. 42). Brouha spent three months in 1934 and four months in 1935 at the Harvard Fatigue Laboratory.

53. See Chapman, "Long Reach" (n. 45).

Physiology—An Adventurous Field Science

Historians rarely consider physiology among the heroic expeditionary or field sciences, but the early decades of the twentieth century suggest that respiratory, industrial, and exercise physiologists thought otherwise. Much like late-nineteenth- and early-twentieth-century field studies in the natural and social sciences—for example, biology, botany, climatology, ecology, oceanography, ornithology, sociocultural anthropology—the IHAE was part science, part adventure.[54] Indeed, the scientific director of the Fatigue Lab, Bruce Dill, initially feared that there would be too much of the latter and not enough of the former when he learned of Keys's proposed study.[55] His concerns may have been valid. Included in Keys's original proposal, "Life at High Altitudes and the Forthcoming Physiological Expedition to Tibet," was a full-time photojournalist, who, as a member of the expedition team, would send regular dispatches of the group's heroic scientific feats to the *New York Times*. Perhaps fearing that his enthusiasm to scale twenty-thousand-foot mountains in pursuit of physiological truths would elicit more than one raised eyebrow, Keys protested,

> There is little adventure in the project, beyond the eternal scientific adventure of the search for knowledge. We expect, from some experience, principally hard work and a great deal of discomfort. But we are confident that the results will amply repay our efforts. Above all we are anxious to bring added conviction to the belief in the study of normal man.[56]

These words were in keeping with the image of the heroic field scientist made popular by nineteenth-century natural scientists such as John Tyndall, whose studies of glacier motion found him traversing dangerous, icy crevasses, and Joseph Hooker, whose trek in the Himalayas allowed him to link altitude to the process of speciation. Such scientific adventures were an increasingly important way of validating the nineteenth-century

54. In spite of physiologists' many forays into the field and the development of environmental physiology, the discipline has been conspicuously absent from historical analyses of field research in the nineteenth and twentieth centuries. See, e.g., surveys of the field sciences such as Robert Kohler and Henrika Kuklick, eds., "Science in the Field," special issue of *Osiris, 2nd Series* 11 (1996). See n. 10 above for more on the epistemological functions of climatic heroism.

55. See David B. Dill, "Ten Men on a Mountain," in *Environmental Physiology: Aging, Heat, and Altitude: Proceedings of Life, Heat, and Altitude Conference*, ed. Steven M. Horvath and Mohamed K. Yousef (New York: Elsevier/North Holland, 1981), 453–66.

56. University Records, Harvard University, Records of President James Bryant Conant, Official Correspondence, 1933–1953. Proposal by Ancel Keys, "Life at High Altitudes and the Forthcoming Physiological Expedition to Tibet," 11, "Expeditions, 1931–1935" folder, UAI 5.168, box 30, Harvard University Archives.

field scientist's character and reputation; they constituted evidence that an individual was willing to travel to the remotest regions of the earth and to sacrifice personal safety in the pursuit of new knowledge about the natural world—knowledge that was frequently employed by imperial powers to exploit the natural resources—animate and inanimate—of colonial territories.

In some ways, the natural world itself was not the focus of the HFL field physiologists. As they ascended to ever greater heights in the Andes, IHAE members directed their gaze inward, focusing on their own blood chemistries, lactic acid thresholds, and psychological functioning. The HFL scientists valued the natural world in which they moved much as they valued the hypobaric chamber inside their laboratory: for the particular climatological circumstances that each afforded. IHAE party members assumed that the data they collected on themselves and their subjects were of an ecumenical nature and could be generalized to individuals who lived and worked at comparable altitudes, whether traveling in the unpressurized cabin of an airplane or trekking in the Himalayas. Here is where the continuity with earlier colonial sciences of acclimatization is most explicit. The South American context for the expedition was determined in part by American neocolonial mining interests, interests, as we shall see, that helped ensure a safe voyage for the scientists. Likewise, Keys billed the data obtained on the expedition as potentially useful to American mining and aviation companies. Indeed, Ross McFarland's extended stay in South America, following the expedition, was a case in point; it was underwritten by Pan American–Grace Airways, a company that eventually employed McFarland to pursue human factors research that would ensure flight safety at high altitude for pilots and passengers alike.

To ensure that their Andean data would serve other contexts, the group employed the latest physiological equipment—Van Slyke and Haldane apparatuses and Grollman machines for measuring respiratory gases in the blood, an electrocardiograph and a cardiotachometer for measuring heart performance, other equipment for measuring blood lactic acid levels, bicycle ergometers for work-output studies, and batteries of psychological tests—to precisely quantify human respiration, metabolism, and psychological performance in the field. They specially outfitted mobile laboratories in railroad cars to bring this equipment with them to the high Andes. If, as Ancel Keys asserted, sustained tests of the "normal man's" ability to acclimatize to heights up to twenty thousand feet required "at least three or four weeks—an unendurable length of time to live in an evacuated steel chamber even if all the conditions of high altitude could be faithfully duplicated," the expedition members would simply transform the mountain into their laboratory.[57]

The HFL scientists would be embarking on the largest, highest, longest, most technically sophisticated high altitude expedition to date in their study of acclimatization. The expedition's "elevated" status would allow its scientists to settle what Keys deemed "the most stimulating controversy in the history of the study of respiration—that between Haldane's school arguing for oxygen secretion in the lung and the disciples of passive diffusion, Barcroft, Krogh, and their followers"—and to illuminate step-by-step the integrated physiological processes taking place during acclimatization over time.[58] For Keys, the postdoctoral fellow of Barcroft and Krogh, finding a definitive answer to the physiological battle royal between his mentors and John Scott Haldane constituted both a major contribution to human physiology and a sort of coming-of-age ritual, one in which he ascended to an unprecedented height to provide the definitive data his mentors lacked.

The IHAE was also a test of the methods of modern physiology to measure the biochemical changes taking place within the respiratory systems of humans and vertebrates and to formulate "a precise quantitative description in multi-variable terms, of the whole course of adaptation to great altitudes and re-adaptation to the lowland."[59] These data would be paired with behavioral and psychological data collected on expedition members by psychologist Ross McFarland, a step that no other high altitude expedition had taken. Such an integrative approach defined the research style of the Fatigue Lab and mirrored an important shift within general physiology from the *mechanistic* materialism of scientists such as Jacques Loeb to the *holistic* materialism of Henderson, Barcroft, Cannon, and others. Focusing on the relationship between biochemistry and behavior during acclimatization also promised to make the results of the IHAE directly relevant to the aviation and mining industries. Psychophysiological studies of normal men acclimating to extraordinary circumstances might prove as useful to business and government, Henderson, Dill, and Keys hoped, as physiological studies of diseased men had proven to clinical medicine. In short, the scientific ambitions of the expedition were as lofty as the mountains Keys intended to climb.

57. Ibid., 4.
58. Ibid., 3.
59. Ibid., 6.

Location, Location, Location

For his study of acclimatization, Keys desired a very high mountainous region (upward of twenty thousand feet), and one with a permanent (presumably fully acclimatized) community. Of course, he also required permission to climb there. Circumstances forced him to pursue not one but three locations. The Pamirs, a mountain range that was part of the Soviet Union and shared a border with the Himalayas, was Keys's first choice, for it boasted a large high altitude population whose physiological characteristics could be compared easily to those of expedition party members. In spite of the Soviets' ongoing campaign to promote the region as a case study in the glories of peasant society and the great modernization works of the Soviet state, Keys's inquiries with the Soviet embassy were ignored.[60] So he turned to his second choice, the province of Ladakh in the Indian state of Kashmir, bordering on the Karakoram mountain range.

In 1935, this region, known as Little Tibet, was under the jurisdiction of the British Raj. The people of Ladakh were mostly of Tibetan ancestry and tilled their lush highland fields at elevations as high as fifteen thousand feet, a fact Keys and others took as an indication of their complete adaptation to altitude. Keys also reasoned that this population would be likely to cooperate with the scientific team, for it had been "renowned for centuries for its friendly and admirable qualities and the traveler in their country, once armed with the sparingly-given official permits, can expect only courtesy and good humor from the inhabitants."[61] Here Keys, like so many field researchers before him, relied on the colonial enterprise to secure a safe location, with helpful indigenous subjects, for his expedition's scientific work.

Joseph Barcroft helped Ancel Keys secure the necessary permissions for travel within Ladakh. On December 31, 1934, however, with the expedition's scientific and climbing equipment and durable provisions safely aboard a Karachi-bound freighter, L. J. Henderson received word from Barcroft that the Raj had rescinded permission for the group's passage to Little Tibet. Crop failure had left the region in an "unstable" state, and visitors might not find the warm and hospitable welcome they expected. The Fatigue Lab staff responded swiftly: Keys, already making his way to South Asia by air, was recalled; HFL physiologist Will Forbes was dis-

60. The Pamiri peoples were featured regularly in *USSR in Construction*, perhaps the greatest propaganda journal published by the Soviets between 1930 and 1941. See Vicki Goldberg, "From a Soviet Magazine that Made a Revolution of Its Own in Design," *New York Times*, April 12, 1996, C27.

61. Keys, "Life at High Altitudes" (n. 56), 10.

patched to New York to cajole longshoremen there into unloading the expedition's crates on New Year's Eve; and Henderson and Fatigue Lab scientific director Bruce Dill tried to decide if canceling the expedition altogether would compromise the unit's reputation.

Deciding in the affirmative, Dill suggested the Andes of northern Chile as a new site for the study.[62] His rationale was simple: the third venue had to work, and Chile possessed many attributes that boded well for the trip. The area was efficiently served by British- and American-built railroad lines, and Cerro Aucanquilcha supported both the world's highest permanent population, sulfur miners living at 17,500 feet, and the world's highest mine, located at an elevation 1,500 feet higher. Moreover, Dill was well acquainted with the impressive work of Peruvian high altitude physiologists Carlos Monge and Alberto Hurtado, individuals who might assist with planning. A 1924 graduate of Harvard, Hurtado had spent three weeks at the Fatigue Lab before studying physiology with William McCann at the University of Rochester from 1931 to 1933. By 1934, he had won funding from the Rockefeller Foundation to outfit his laboratory at the Institute of Andean Biology in Lima, using the HFL as his model.[63] Heavy American investments in Chilean mining, infrastructure, and air routes also promised a smooth journey.[64] Likewise, the second presidency of Arturo Alessandri, commenced in 1932, restored democratic rule and political and economic stability to Chile after the Great Depression had unsettled the nation and led to a brief socialist revolution.[65] Chile, in short, seemed an excellent venue for the expedition.

Keys began making preparations immediately. Winter in the southern hemisphere was not an ideal time to conduct research at high altitude, but the Atacama Desert, made popular by geographer Isaiah Bowman, was one of the driest places on earth.[66] There would be significant snow cover at altitude, but the mine operated year round, and so, the physiologists hoped, could they. On March 22, less than three months after the

62. See David B. Dill, "Ten Men on a Mountain" (n. 55). Dill claimed that his inspiration for the choice of Cerro Aucanquilcha came from reading an article by geographer and popular writer Earl Parker Hanson. See Earl Hanson, "Out-of-the-World Villages of Atacama," *Geog. Rev.* 16, no. 3 (July 1926): 365–77. Dill's connections to the Rockefeller Foundation and Hurtado suggest that there may have been additional reasons to select Chile as the site of the high altitude expedition.

63. Hurtado's experience at HFL is mentioned by Dill, "Ten Men on a Mountain" (n. 55). See also Marcos Cueto, "Andean Biology in Peru" (n. 9).

64. See "Our Interests Wide in Chile," *New York Times*, June 6, 1932, 8.

65. Skidmore et al., *Modern Latin America* (n. 15), 288.

66. Isaiah Bowman, *Desert Trails of the Atacama* (New York: American Geographical Society, 1924).

aborted departure from New York Harbor, Keys and his advance team departed for South America.

Ten Men on a Mountain

Having suggested the Andes as the expedition location, Bruce Dill joined the group, playing his familiar role of chief scientific officer. Other members of the scientific team included E. Hohwü Christensen, an exercise physiologist who had collaborated with Keys at Krogh's University of Copenhagen lab. Christensen led the studies of work performance on the expedition. Harold T. Edwards, an indispensible Fatigue Lab technician without formal physiology training, supervised all of the blood tests performed during the expedition and conducted studies on lactic acid levels in response to exercise at altitude. William Forbes, a Fatigue Lab physiologist who had earned his Ph.D. under Barcroft at Cambridge, was Dill's second in command; Forbes examined blood sugar and pH levels on the slow ascent. Duke comparative physiologist F. Gregory Hall had charge of an array of high altitude and sea-level mammals, measuring their ability to adapt to ever higher heights; he also oversaw spectroscopic blood work for the entire group. Columbia University physiological psychologist Ross McFarland, who would pioneer the field of human factors research in the aviation industry, investigated the effects of altitude on mental performance, affect, and the special senses (vision, hearing, smell, and taste). Mass General physician John Talbott supervised blood acid-base studies and handled medical problems encountered by the group. Peruvian physician E. S. Guzman Barron, an accomplished biochemical researcher at the University of Chicago, joined the group as translator and lent his expertise to several research projects. British neurophysiologist Bryan Matthews supervised electrocardiography within the exercise physiology studies. The most experienced mountain climber of the group, Matthews guided the researchers at the highest altitudes. Meanwhile, Keys, the "general manager and organizer" of the expedition, contributed to a range of experiments led by the others. Thus, the organization of the IHAE was remarkably similar to that of the Fatigue Lab in terms of its multidisciplinary mix of researchers, who cooperated fully in their own and others' research programs. Importantly, each scientist also served as an experimental subject, so that his own ability to adapt to altitude could be compared with that of his confreres and with the mental and physical performances of the Chilean sulfur miners at Cerro Aucanquilcha.

Funding for the expedition came from a variety of sources, if principally academic ones. The universities of Harvard, Duke, Columbia, Copenhagen, and Chicago all contributed materially and financially to the support of their respective faculty. Rockefeller monies, already underwriting the Fatigue Lab, were secured along with financial contributions from the Royal Society of London, the Danish Rask-Orsted Fund, the Josiah Macy Foundation, and the Corn Industries Research Foundation. The Parke-Davis Company and the Laboratory of the California Citrus Growers supplied medicines and vitamin concentrates for expedition members. The British-owned railroad company Ferro-Carril de Antofagasta a Bolivia (FCAB) loaned four of its rail cars to the expedition: one for the animals and comparative physiology work; another for sleeping; a kitchen car; and a steel box car for exercise and respiration experiments, general chemical work, and blood gas analysis. Arriving in the northern port city of Antofagasta from their various points of origin, the IHAE members took their scientific equipment 150 miles inland to the world's largest copper mine at Chuquicamata. There the Guggenheim-owned Chilean Exploration Company, which controlled the mine, helped the scientists outfit the railroad cars for the remainder of the trip.

If the experimental equipment that the Fatigue Lab scientists brought with them was elaborate—and by all accounts it was—the general protocol of the expedition was not. The group moved slowly from sea level to successively higher altitudes, performing batteries of tests along the way. Baseline physiological and psychological measurements for most of the party members were made at sea level, prior to departure, in Cambridge, Massachusetts, and New York City. These data were compared with those collected at several different high altitude points along the railroad line to Cerro Aucanquilcha, which was located on the Bolivian border: Chuquicamata (9,200 feet), Ollagüe (12,020 feet), Collahuasi (15,440 feet), Aucanquilcha miners' village (17,500 feet), and Aucanquilcha summit (20,140 feet). At the invitation of the sulfur mine owners Señores Juan and Hipolito Carrasco, the IHAE team moved their mobile lab inside the FCAB freight cars to the 'Quilcha mine headquarters at 17,500 feet.[67]

The extensively equipped field laboratory, the long duration of the expedition, and the slow ascent to the highest altitudes allowed Keys and his fellow scientists to measure the minute physiological changes taking place in their own bodies (and those of the animals that accompanied them) as they adapted to altitude. The additional weeks of acclimatization also provided time to make blood and respiratory measurements on the miners. Indeed, in spite of the expedition's primary focus on its mem-

67. For full accounts of the expedition, see Keys, "Physiology of Life at High Altitudes" (n. 3), and Dill, "Ten Men on a Mountain" (n. 55).

bers' responses to cold, low pressure, and hypoxia, Keys, Dill, and their team regarded the well-acclimated miners as "normal" or even "supernormal" subjects of study. They assumed that years of living and working at extreme altitude had allowed the Chileans to adapt more fully than they themselves had adjusted to the climatic stress. The HFL scientists thought that both Andean natives and expedition "aliens" acclimated via the same processes, even if three months at altitude was not enough time for the scientists to adapt fully.

In 1936, Ancel Keys published an overview of the IHAE, portraying it as an adventure-filled scientific success to readers of the *Scientific Monthly*. Keys's piece was intended for a general audience, and he saw to it that national newspapers also covered the story.[68] Twenty-one articles and several chapters appeared in a wide range of English-language scientific journals and books between 1936 and 1938. As Keys had envisaged, the great Haldane–Barcroft debate over oxygen secretion at altitude was resolved—in Barcroft's favor—as passive diffusion did account for the transmission of oxygen from the air to the lungs and blood. Harold Edwards discovered the "lactate paradox," that lactic acid levels associated with heavy exercise actually decrease at altitude.[69] Keys, Matthews, Forbes, and McFarland identified a range of factors that could be used to predict individuals' ability to acclimate successfully: age, body size, resting pulse, and blood alkaline reserve.[70] Forbes and McFarland offered their services to measure the effects of alcohol consumption at altitude and determined that for a constant amount of liquor consumed, blood alcohol levels rose faster and declined more slowly with altitude. McFarland found little decrease in the mental capability of expedition members at moderate altitude, but this was not true for the highest stations, where mental and sensory capacities declined more markedly and variably among members, relative to their physiological acclimatization. His series of four psychophysiological papers became classics in the aviation industry, the results factoring into

68. See Waldemar Kaempffert, "Fatigue at Heights—Tibetan Expedition is to Study Problem Affecting Aviators," *New York Times*, June 17, 1934, XX6; William Barton, "Our Expanding Universe," *Los Angeles Times*, November 29, 1936, H15; Ancel Keys, "The International High Altitude Expedition," *Harvard Alum. Bull.* 38 (1935): 176–80.

69. H. T. Edwards, "Lactic Acid in Rest and Work at High Altitude," *Amer. J. Physiol.* 116, no. 2 (July 1936): 367–75.

70. Ancel Keys, Bryan H. C. Matthews, W. H. Forbes, and Ross A. McFarland, "Individual Variations in Ability to Acclimatize to High Altitude," *Proc. Roy. Soc. London* 126, no. 842 (September 23, 1938): 1–24.

the Pan American Airways pilot manual *Keeping Fit for Flying: An Analysis of Important Factors Influencing the Health and the Efficiency of Civil Airmen.*[71]

The fourth paper in McFarland's series examined his results from tests performed on eighty-five Quechua and mestizo men—miners and yareta gatherers at high altitude and railroad workmen at sea level.[72] McFarland concluded that the respiratory functioning of the high altitude men was extraordinarily efficient and akin to that of athletes at sea level, but that their hearing and reaction times suffered in comparison to the railroad employees, most probably because of neurocirculatory deficits linked to low oxygen pressure at high altitude, to the wind and dry weather that the miners and yareta gatherers contended with daily, and to the men's lack of familiarity with the tests. Expedition members' interpretations of the differences in acclimatization and performance between themselves and the miners and shepherds they encountered, however, are where the primacy and persistence of environmental determinism, the Andean politics of *indigenismo*, and the neocolonial nature of the IHAE were most in evidence.

Scientists, Normal Men, and Andean Men

A decade prior to the IHAE, physiologist Joseph Barcroft had published his report on the Anglo-American expedition to Cerro de Pasco, Peru. In *The Respiratory Function of the Blood—Part 1: Lessons from High Altitudes*, Barcroft had marveled at the "Cholo" women who danced the night away at fourteen thousand feet, and he had observed with awe the child miners who hauled on their backs forty-pound "load[s] of metal . . . from the bowels of the earth."[73] Yet, if such individuals were "capable of perform-

71. Ross McFarland, "Psycho-physiological Studies at High Altitude in the Andes I. The Effects of Rapid Ascents by Aeroplane and Train," *J. Comp. Psychol.* 23, no. 1 (February 1937): 191–225; McFarland, "Psycho-physiological Studies at High Altitude in the Andes II. Sensory and Motor Responses during Acclimatization," *J. Comp. Psychol.* 23, no. 1 (February 1937): 227–58; McFarland, "Psycho-physiological Studies at High Altitude in the Andes III. Mental and Psycho-Somatic Responses during Gradual Adaptation," *J. Comp. Psychol.* 24, no. 1 (August 1937): 147–88; McFarland, "Psycho-physiological Studies at High Altitude in the Andes IV. Sensory and Circulatory Responses of the Andean Residents at 17,500 Feet," *J. Comp. Psychol.* 24, no. 1 (August 1937): 189–220. See McFarland, *Keeping Fit for Flying* (n. 17), esp. 17–114.

72. Yareta is a desert "peat" that grows in compact clusters throughout the highlands of South America. It is used for fuel.

73. Barcroft was not sure what to call "the native of the mountains" in Peru and decided upon the term "Cholo," which was the vernacular term he heard used "to describe any man who wears a poncho in any part of Peru." The term, however, was often used disparagingly

ing feats of physical strength and endurance which are very surprising," Barcroft was not prepared to consider these residents as completely adapted to altitude.[74] The English physiologist concluded his "lessons from high altitudes" by asserting, "All dwellers at high altitudes are persons of impaired physical and mental powers."[75] Such a perspective echoed European prejudices against non-Western populations—populations frequently praised by "metropolitans" for their physical strength and athletic prowess, but pitied for their limited mental capacity.[76]

Regardless of the Cambridge physiologist's reasoning, it is clear that he believed that it was unlikely that the selective forces of hypoxia and low barometric pressure had been at work among the Andean natives in any evolutionary sense, selecting the fittest since the time of the Incan Empire. Instead, Barcroft concluded, largely from changes in facial complexion and, in the case of the expedition party, blood tests, that both native Andeans and Europeans suffered markedly from want of oxygen at altitudes over fourteen thousand feet.[77] In actuality, Barcroft's respiratory data on the Andeans were scant; the expedition party had neither the time nor the language skills to train native subjects from the local population in the scientific protocols required for accurate measurements. Dismissing the Andeans as subjects of "low mentality . . . who speak a language that is not understood by the observer," Anglo-American expedition members interpreted the "barrel chests" and clubbed fingernails so common among the indigenous population as signs of the power of altitude to distort physique, never considering that the Andeans' larger chests might afford them an advantage in terms of lung capacity. Instead, the Andean miner was said to possess "the aspect of pouter pigeons," with a chest "out of

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by the Peruvian elite to describe individuals of Amerindian ethnicity. Barcroft intended the term to mean "the man in the street of Cerro, excluding on the one hand, his ruler of Spanish ancestry, and on the other, his employer of Anglo-Saxon parentage": Joseph Barcroft, *The Respiratory Function of the Blood—Part 1: Lessons from High Altitudes* (Cambridge: Cambridge University Press, 1925), 37.

74. Ibid., 38–41.

75. Ibid., 176. Barcroft's position on the "Cholos" of Cerro de Pasco may have also stemmed from his own admittedly poor capacity to adapt well to high altitude.

76. Lossio, "Life at High Altitudes" (n. 9), esp. chap. 4, which focuses on Carlos Monge and his theory of the superior adaptation of "Andean Man" to altitude. NB: All discussions of Carlos Monge and Alberto Hurtado rely exclusively on works published in English; I am especially indebted to historians Jorge Lossio and Marcos Cueto.

77. Barcroft called one such man, an engineer from the mine who accompanied expedition members down "the hill" by train, "a cross between a chameleon and a barometer," though he admitted that such a characterization was "undignified." See Barcroft, *Respiratory Function of the Blood* (n. 74), 51.

proportion with his stature."[78] Barcroft, in short, seemed of a piece with those acclimatization scientists of the nineteenth century who projected their fears of the alien environments of the colonies, and the threats they posed to European health, onto the bodies of indigenous populations.

Barcroft's assessment of Andean peoples by the "normal" values of European sea-level residents greatly disturbed Carlos Monge, the pioneering Peruvian high altitude researcher. Monge had trained at the London School of Tropical Medicine and served on the faculty at the medical school of the University of San Marcos in Lima. Born into a poor Lima family of mixed European and Indian ethnicity, Monge embraced the 1920s rise of *indigenismo* politics, a movement in Peru and other Latin American nations that attempted to restore the cultural pride and citizenship of Indian populations (especially those of the Andes). Within this framework, Barcroft's conclusions about the inferiority of Andean natives to sea-level dwellers in the "two Cambridges" smacked of ignorance, arrogance, and singular misjudgment. Monge responded by launching his own expedition in 1927 to demonstrate the superior adaptation of Peruvian high altitude dwellers to their arid, hypoxic, low-pressure environment; he referred to them as a distinct race, "Andean Man."[79] Tireless in his quest, Monge had by 1931 founded the Institute of Andean Biology. Three years later, the institute had received its first Rockefeller grant to support a laboratory for the research of Monge's colleague Alberto Hurtado. Over the next seventeen years, the Rockefeller Foundation channeled more than $100,000 to the institute to support its research. Ironically, then, Barcroft's estimation of the Cholos' inferior physiology helped initiate what became one of the most active, longest-lived high altitude research programs in the world.

Ever the climatic determinist, Monge understood the people of the Andes as a distinct racial variety, molded over dozens of generations by exposure to hypoxia:

> It can be definitely stated that the Man of the Andes possesses biological characteristics distinct from those of sea-level man. It can be said that these characteristics mean that he belongs to a climatic variety of the human race as Piery inclines to believe or to a physiologic variety as Cannon thought likely. . . . Andean Man being different from sea-level man, his biological personality must be measured with a scale distinct from that applied to the men of the lower valleys and plains.[80]

78. Ibid., 42–49.

79. See Cueto, "Andean Biology in Peru" (n. 9) and Lossio, "Life at High Altitudes" (n. 9).

80. Monge, *Acclimatization in the Andes* (n. 12), xi–xii. For an earlier statement, see Monge, "High Altitude Disease," *Arch. Internal Med.* 59 (January 1937): 32–40, quotation on 32: "A man who is acclimated to the high plateaux of the Andes . . . is, *sensu strictori*, one who by

Monge's citation of Marius Piery, whose career in climatological medicine is discussed by Mike Osborne and Rick Fogarty in this issue, reflected his status not only as a neo-Hippocratic, but also as a Lamarckian, for he believed that climatically induced changes in physique and physiology might be passed from one generation to the next. "Our objective is a different one," offered Monge in the introduction to his 1948 treatment of acclimatization in the Andes: "it is the study of the races that people the uplands among whom there predominate genetic factors of both hereditary and acquired type."[81] For Monge, human beings were very much the manifestation of their native climate. In this regard, his ideas of climatic racial physiology resembled not only those of Piery but also the arguments of Radhakamal Mukerjee, discussed by Alison Bashford. Rather than focusing on natives and territories of South Asia and the southern hemisphere, however, Monge hoped to provide a physiological rationale for the re-enfranchisement of Andean natives. High altitude, low barometric pressure, aridity, solar radiation, and "ionization of the atmosphere" had "evolved an ethnic type with morphological and biological characteristics distinct from those of other groups that people the earth." These conditions were those to which the lowlander European might "adapt," but it took generations of "climatic aggression" to truly "acclimatize."[82] Andean Man was the product of this *longue durée* process.

Invoking both real and mythic pasts, Monge's *Acclimatization in the Andes* was very much a history lesson focused on the successes of the Incan Empire and later Andean peoples in responding in superior physiological fashion to the Spaniards and other invading lowlanders over the centuries. Monge believed that this advantage obtained only at high altitude, however. Indeed, as he detailed the special morphology and physiology of the Andean peoples, Monge also enumerated the health problems high altitude natives faced when they descended to sea level. By examining the history of the South American "wars of independence," for example, one could see more clearly the important role of "climatic aggression"—of mountain sickness and "sea-level sickness"—as a factor in military conquest.[83] Monge encouraged historians, sociologists, and anthropologists, not just physiologists, to redirect their efforts to pursue

ancestral or acquired changes has the racial characteristics which allow him to behave physically and mentally like a man living at sea-level."

81. Monge, *Acclimatization in the Andes* (n. 12), xv.

82. Ibid., xv–xvii.

83. Ibid., xvi–xviii. See also William L. Laurence, "Finds a New Race High in the Andes—Dr. Monge, Peruvian Scientist, Says 'Stratosphere Man' Is Physiologically Unique," *New York Times*, September 24, 1941, 18.

research that would better appreciate the ways in which high altitude climates had influenced social structure and custom.[84] An idiosyncratic climate, he claimed, shaped a unique people, whose social customs and organization were likewise unique and demanded special consideration. The *indigenista* physiologist was concerned that both the physiological and the social problems of high altitude populations had been ignored by lowland researchers who prioritized their own ability to adapt to great heights.

Monge's championing of "Andean Man" left no doubt that he was a human biologist committed to making his understanding of the "man–environment" unit relevant to social and political policies as well as a general understanding of high altitude physiology. As Marcos Cueto and Jorge Lossio have observed, however, Monge's *indigenismo* politics made him a relativist, who believed that the makeup of the Andeans and the science of the Andean region were unique to that part of the world alone.[85] Views such as this were well received in many quarters and helped the Institute of Andean Biology attract the support of a Peruvian government that promoted an *indigenismo* agenda between the two world wars. Although not as patently political as Monge, the IHAE physiologists were also influenced by the politics of their time, specifically those of American neocolonialism. Their ecumenical understanding of acclimatization as a short-term process placed "Andean Man" and lowlanders on equal footing. They believed those of European extraction had the potential to acclimate well and thrive at altitude, thereby offering reassurance to American corporations interested in investing in Chile or any Andean region for that matter. The IHAE scientists' interactions with both Monge and Hurtado are interesting in this regard.

At both ends of their trip, the IHAE scientists engaged Monge and his colleague, and later successor at the Institute for High Altitude Biology, Alberto Hurtado. Monge's junior by several years, Hurtado was equally respected as a physiologist, but was more of a laboratory experimentalist than Monge, who was known for his clinical, ecological, and cultural interests. Hurtado was in the process of outfitting his laboratory, modeled after the HFL, when the IHAE visited him and Monge in 1935. Meeting

84. In the 1950s, Carlos Monge teamed with Cornell anthropologists to study the social and medical problems of the rural Andean community of Vicos. See Lossio, "Life at High Altitudes" (n. 9), chap. 4; Jason Pribilsky, "Modernizing Peru: Negotiating *Indigenismo,* Science, and the 'Indian Problem' in the Cornell-Peru Project," in *Vicos and Beyond: A Half Century of Applying Anthropology in Peru,* ed. Tom Greaves, Ralph Bolton, and Florencia Zapata (New York: Rowman & Littlefield, 2011), 103–27.

85. My discussion of Monge relies heavily on Marcos Cueto, "Andean Biology in Peru" (n. 9).

with Monge and Hurtado proved prudent, for it emerged in the course of their initial visit that Barcroft had deeply offended Monge's sensibilities by failing to visit him when the Anglo-American expedition passed through Lima, on their way to Cerro de Pasco in 1921. The IHAE made no such slight and instead drew both Monge and Hurtado into their research program.

In 1936, Talbott and Dill published the first article in a U.S. scientific journal to recognize chronic mountain sickness, referring to the condition eponymously as "Monge's disease" and discussing Carlos Monge's research on altitude sickness in great detail.[86] Indeed, Monge became a sort of ex post facto member of the expedition, when he published, at the urging of Guzman Barron, an article on diseases of high altitude and their differential diagnosis in the prestigious *Archives of Internal Medicine*.[87] Dill included Monge's essay in the master list of publications based on data collected by the IHAE scientists—a gesture that may be seen at once as a tribute to the important role he thought Monge had played in the development of high altitude medicine and as an act that might maintain good relations with the director of the increasingly prominent Institute of Andean Biology.

In 1937, the same year that Monge's *Archives* article appeared, expedition members Dill, Edwards, and Guzman Barron also published an article with Alberto Hurtado on acute mountain sickness.[88] The article was based on collaborative work done with the Institute of Andean Biology, when the IHAE scientists passed through Lima on their way home. Using the same railroad line as Barcroft had a decade and a half earlier, the group ascended to fourteen thousand feet rapidly and found that taking ammonium chloride, then thought to help with altitude sickness, made matters worse. Hurtado, unlike Monge, regarded the process of acclimatization as one that could be acquired in a lifetime and did not consider the Andean people as a "climatic-physiological race."[89] Thus, through their collaborations with Monge and Hurtado, IHAE scientists maintained cordial relations while promoting their own understanding of acclimatization.

Indeed, the publications of the IHAE scientists showed remarkable consistency in their conclusion that lowlanders, regardless of their eth-

86. John Talbott and David B. Dill, "Clinical Observations at High Altitude: Observations on Six Healthy Persons Living at 17,500 Feet and a Report of One Case of Chronic Mountain Sickness," *Amer. J. Med. Sci.* 192 (1936): 626–39.

87. Monge, "High Altitude Disease" (n. 81).

88. E. S. Guzman Barron, D. B. Dill, H. T. Edwards, and A. Hurtado, "Acute Mountain Sickness: The Effect of Ammonium Chloride," *J. Clin. Invest.* 16, no. 4 (July 1937): 541–46.

89. For more on the contrasting personalities and science of Monge and Hurtado, see Cueto, "Andean Biology in Peru" (n. 9); quotation on 656.

nicity, *could* adapt as successfully to great heights as men who had lived at altitude their entire lives. They believed, however, that a certain length of time, approximately a year, was necessary for full acclimatization to take place in most cases. Evidence for this conclusion came from two sources. The first was the fact that the IHAE scientists saw their own respiratory measures coming in line with those of the Chilean miners over time. And the second was the scientists' experience with the miners themselves. Observed Ancel Keys, "We were surprised to learn that many of the best 'old-timers' at the mine are Chileans, born and bred near sea level. The Andean peoples are by no means immune to 'soroche' or 'puna' [altitude sickness], and many lowland people are able to compete with them successfully in their own habitat after some months of acclimatization."[90] To the expedition members, then, it seemed that the "sea-level man" and the "high altitude man" were both "normal" men whose bodies were capable of responding well or not so well to extraordinary environmental circumstances—a position that supported the expansion of American and European business interests in Chile.

Conclusion: The IHAE and the Career of Ancel Keys

Two years after Ancel Keys returned from Chile, he established the Laboratory of Physiological Hygiene (LPH) at the University of Minnesota. Keys's research program took as its organizing theme "the study of the entities which are loosely termed 'fitness,' 'health,' and 'fatigue.'" Like Henderson before him, Keys admitted that these terms were vague, but he insisted on their importance in developing a science of normal human functioning. His goal was to provide objective, quantifiable measures of human performance—physiological and psychological—that would clarify the troublesome concepts. In the process of examining the effects of such "independent variables [as] temperature, exercise, training, sleep, posture, diet, oxygen supply" on individuals at work, at play, in the laboratory, and on the battlefield, Keys hoped

> there [would] emerge the beginnings of a real science of physiological hygiene. The goal toward which we should like to contribute is the utopian situation in which, from a study of the given individual now, it would be possible to predict both short time and long range physiological results from a given mode of life, personal habits, activity, and diet.[91]

90. Keys, "Physiology of Life at High Altitudes" (n. 3), 303.

91. Keys, "Notes on the Laboratory of Physiological Hygiene, University of Minnesota," February 9, 1945, 3, University Archives, University of Minnesota, Minneapolis.

The stamp of the HFL was unmistakable. Keys wished to take physiology out of the pathological world of the clinic and put it to use in the "normal" realms of industry, public health, and *preventive* medicine.

The field approach of the HFL, focused on performance in environments of moist heat, dry heat, high altitude, and extreme cold, was well suited to a far less utopian context, however: wartime research. Keys's LPH, like the Fatigue Lab, was drafted to serve the United States and its allies in a variety of capacities during World War II. When in 1940 the U.S. Army sought assistance to develop a lightweight, compact ration for paratroopers, the Army quartermaster called upon Ancel Keys.

Keys's experience at high altitude, matched with his ability to organize a major physiological expedition pairing lab and field studies, and scientific as well as industrial interests, made him an ideal candidate to develop a nutritionally complete meal for mobile fighting men—men who found themselves in a diversity of climates in the European and Pacific theaters. Testing the ration on soldiers and scientists in the lab and field over the course of 1940–41, Keys created the "K-ration." In collaboration with the Army quartermaster, Keys employed a holistic model of research that brought "palatability psychology" as well as nutritional physiology and food biochemistry to bear on the process of ration development, inaugurating a new era of nutritional research with postwar applications throughout the food industry.[92]

Keys's next major scientific project was a laboratory study of semistarvation or extreme caloric deprivation, sponsored by the federal government and the historic peace churches. Again, Keys brought psychology as well as physiology and biochemistry to bear on a nutritional research problem, observing the responses of thirty-six conscientious objectors as they lost 24 percent of their body mass by consuming 1,500–1,800 calories per day over six months. The resulting fourteen-hundred-page monograph, *The Biology of Human Starvation,* became an instant and enduring classic in the fields of human nutrition, abnormal psychology, and nutritional physiology.[93] Keys sent bulletins of his findings to the United Nations Relief and Rehabilitation Administration and disseminated his results to the allied

92. See Ancel Keys, "Rations for Air-Borne and Other Mobile Troops," *Quartermaster Rev.* 21 (September–October 1941): 26–28, 81; Isker and Keys, "Ration in Combat" (n. 6). See also Alissa Hamilton, "World War II's Mobilization of the Science of Food Acceptability: How Ration Palatability Became a Military Research Priority," *Ecol. Food Nutr.* 42 (2003): 325–56; H. L. Meiselman and H. Schutz, "History of Food Acceptance Research in the U.S. Army," *Appetite* 40 (2003): 199–216.

93. Keys et al., *Biology of Human Starvation* (n. 6).

commanders who were daily confronting the emaciated and displaced peoples of Europe.[94]

In 1958 Keys launched the Seven Countries Study, a prospective, longitudinal, epidemiological study of diet and heart health among twelve thousand people in seven countries throughout Europe, Asia, and North America.[95] Keys trained physicians and physiologists alike to measure and record a wide array of physiological and nutritional data in "normal men" across the world in his effort to determine the role of diet and other factors in the etiology of coronary heart disease. As with the IHAE, Keys brought an international, holistic, and ecological perspective to bear on a significant physiological problem: the development of heart disease. His work was pioneering, but he was hardly alone in his approach to heart disease epidemiology. This style of thinking constituted an important current in epidemiological thought in the 1940s, one that shaped the Framingham Study.[96] Today, we are aware of the health benefits of the "Mediterranean Diet" in large part because of the Seven Countries Study and the best-selling cookbook, *Eat Well and Stay Well*, that Keys and his biochemist wife Margaret wrote in 1959.[97] Returning to the birthplace of Hippocratic medicine, Keys demonstrated in his subsequent epidemiological studies, as he had in his high altitude research, the power and persistence of place to shape diet, health, and disease in the twentieth century.

The HFL, wrote Carleton Chapman in 1990, had a "long reach."[98] By this he referred to the laboratory's role in training two generations of productive scientists within environmental, exercise, and respiratory physiology—individuals trained to explore humankind's adaptation to extreme environments from biomedical, ecological, social, and political standpoints. The IHAE and Ancel Keys represent the farthest extension of that reach. Keys carried the interdisciplinary methodology of the Fatigue Lab—of the nascent field of human biology—into the Andes, literally and figuratively staking a claim for an applied biomedical and social science

94. See Ancel Keys, Olaf Mickelsen, Austin Henschel, Josef Brozek, and Henry Taylor, "Later Stages of Rehabilitation Following Experimental Starvation in Man" (University of Minnesota, August 1, 1946). This report was locally produced by the Laboratory of Physiological Hygiene for postwar relief workers and was marked, "This Report is not for General Distribution, Publication, or Quotation."

95. Keys, *Seven Countries* (n. 6).

96. Gerald Oppenheimer, "Profiling Risk: The Emergence of Coronary Heart Disease Epidemiology in the United States, 1947–1970," *Internat. J. Epidemiol.* 35 (2006): 720–30, esp. 723.

97. Ancel and Margaret Keys, *Eat Well and Stay Well* (Garden City, N.Y.: Doubleday, 1959).

98. See Chapman, "Long Reach" (n. 45).

of the field that he later called "physiological hygiene." In so doing, he and his colleagues crossed the boundaries of nation and discipline to alter the climate of biomedical research and foster a new hybrid culture where lab, field, and place held equal importance.

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