Part I

The fitness of "fitness": Henderson in context

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Locating "fitness" and L. J. Henderson

Everett Mendelsohn

Crane Brinton, Harvard historian, friend of Lawrence J. Henderson, and fellow member of The Saturday Club, wrote the obituary for Henderson in the Club's third commemorative volume (Brinton, 1958, p. 207). Noting that Henderson was somewhat out of the ordinary – crossing the Charles River on several occasions to keep appointments at the Medical School (Boston) and the College (Cambridge) and then recrossing it to get to the Business School (Boston) – Brinton went on to note Henderson's other non-traditional characteristics: "Ticketed as a biological chemist, he later took the title *physiologist* and, although he would not have liked the name, at the end of his career he was a *sociologist* [emphasis added]."

Brinton went on: "A cross section of his publications may indeed be so drawn up as to seem an academic scandal." Brinton ran through the publications, from the well-known *The Fitness of the Environment* (1913) and *The Order of Nature* (1917); the more esoteric *On the Excretion of Acid from the Animal Organism* (1910, 1911); the simple volume *Blood: A Study in General Physiology* (1928); the unexpected transcript of an interview on the experiments in the Liberty Bread Shop (Brinton, 1958, p. 208); in his later life, *The Study of Man* (1941); to *Pareto's General Sociology: A Physiologist's Interpretation* (1935). Brinton jocularly added that a piece by Henderson – a biographical memoir on the life of the poet Edwin Arlington Robinson (a close friend from his student days) written as a memoir for the American Academy of Arts and Sciences – is to be found in the Woodberry Poetry Room of Harvard's Lamont Library.

To Brinton, "the conclusion is inescapable: Henderson, who was so much else, was also a philosopher." But Brinton also modified his praises: Henderson did not have the gifts of a popularizer. He was not a polymath, despite his interests in many areas. Nor was he a Renaissance figure; he had no interest in music or in the fine

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arts. And – almost mockingly – Brinton noted Henderson's very high regard for "the art of eating and drinking."

So who was this man whose *The Fitness of the Environment*, published some ninety years before, was chosen as the emblem of the project, *Fitness of the Cosmos for Life*?[1]

Who was L. J. Henderson?

Lawrence Joseph Henderson was born in Lynn, Massachusetts, an industrial city just north of Boston, on June 3, 1878. The son of a businessman, he received his early education in Salem, Massachusetts, the more upscale town of his father's family, before going to Harvard as a sixteen-year-old – actually not that unusual in the late nineteenth century. His father's business connections in the St. Pierre and Miquelon Islands of the Gulf of St. Lawrence, where the young Henderson spent his vacations, stimulated his interest in learning French.

After graduating in 1898, he went on to Harvard Medical School, receiving his M.D. degree in 1902 (although he never intended to be a physician). He followed the path of those Americans interested in advanced scientific training by spending two years in the Strasbourg (then in Germany) laboratory of the biochemist Franz Hofmeister. After returning to Harvard, he spent a year in the chemistry laboratory of Theodore W. Richards (his former teacher and later brother-in-law). In 1905, he was appointed Lecturer in Biochemistry at the Harvard Medical School. He then moved to the college and, rising through the ranks, became a professor in 1919. In 1934, he was appointed the Abbott and James Lawrence Professor of Chemistry, a post he held until his death on February 10, 1942.

Henderson was a key figure in establishing the Department of Physical Chemistry in the Medical School (1920), and seven years later he helped establish the Fatigue Laboratory at the Graduate School of Business Administration. Together with Alfred North Whitehead (whom he helped bring to Harvard) and President Abbott Lawrence Lowell, he founded the Society of Fellows at Harvard. As early as 1911, Henderson started teaching a general course in the history of science (one of the earliest in any university) and played an instrumental role in bringing the Belgian George Sarton, the pre-eminent historian of science, to Harvard in 1916. He received the obvious forms of scientific recognition, including election to the National Academy of Sciences (becoming its Foreign Secretary) and the American Academy of Arts and Sciences, and was also decorated with the French *Légion d'honneur*.

But Henderson was not a good experimenter, did not like manipulating the complex apparatus of his field (he later confessed to this in his unpublished series

[1] See www.templeton.org/biochem-finetuning/participants.html.

of "Memories" [1936–39]), was judged by colleagues to be incapable of writing or speaking simply, was known for making "passionate and intolerant assertions and suffered fools not at all." He consciously took the role of gadfly, (often rudely) wanting to shake people out of their comfort zone and stimulate them to respond. Brinton noted that despite his warmth, which he hid from the world, he appeared to many as "a cold scientist, pompous, even pedantic" (Brinton, 1958, pp. 211–12).

Many of those who recounted episodes from Henderson's life or who had encounters with him noted special characteristics. His very fair-minded former student and colleague John T. Edsall, the Harvard biochemist, noted in his entry on Henderson in the *Dictionary of American Biography* that

> his mind and temperament were complex. Especially in his later years, he spoke often with intense distrust of "intellectuals," liberals, and uplifters, who he felt failed to understand the deep non-rational sentiments that are an essential foundation for a satisfactory and stable society . . . he could infuriate some of his hearers . . . *(Edsall, 1973, p. 352)*

George Homans, Harvard professor of sociology and young disciple of Henderson's later work on the social theorist Vilfredo Pareto, put it more bluntly in his own autobiographical volume: "Henderson was always an extreme and outspoken conservative . . . his manner in conversation was feebly imitated by a pile driver" (Homans, 1984, p. 90). Or, as he put it in another context: "Henderson never lost his tastelessness" (p. 117). This, from a deep admirer of his work, a close younger colleague, and the co-author with Charles P. Curtis of a volume on Pareto's sociology.

Where did *The Fitness of the Environment* come from and where did L. J. Henderson go with it? In spite of the several fields in which Henderson worked, a number of commentators, his contemporaries, and later analysts noted a markedly similar approach in many of his endeavors. Looking back at his work later in life, Henderson himself noted more unity than he had been aware of at the time. His focus was on organization and system: the organism, the universe, and society. John Parascandola, the author of a doctoral dissertation and several important articles on Henderson, put it succinctly: "The emphasis in his work was always on the need to examine whole systems and to avoid the error of assuming that the whole was merely the sum of its parts" (1971, p. 63).

But if that is the general outlook – and there is no real contest about this among the commentators on Henderson's work – what were the proximate causes and immediate contexts of Henderson's first full statements of the system of organism and environment? What were its visible and tacit sources? A connected sub-question examines how Henderson's ideas compared with those of other contemporary biologists who were similarly examining the ideas of life and matter: Walter Bradford

Cannon, a Harvard colleague and author of *The Wisdom of the Body* (1932) and of a very full biographical memoir published by the National Academy of Sciences (Cannon, 1945), and Jacques Loeb, a Rockefeller Institute protagonist whose classic essay "The Mechanistic Concept of Life" (1912) stood in sharp contrast to the organicism of the two Harvard scientists.

The obvious first sources for Henderson's fitness argument were the studies he began in 1905 on the equilibrium between acids and bases achieved in the organism. These studies represented some of his most sustained scientific work. The buffer systems he noted served to maintain neutrality in physiological fluids. What he saw in this was "a remarkable and unsuspected degree of efficiency [and] a high factor of safety" (Parascandola, 1968, p. 70). In his 1908 paper "The theory of neutrality regulation in the animal organism," Henderson noted that, in part, this efficiency depended on the properties of some of the substances involved in physiological reactions: that is, the dissociation constants of carbonic acid and monosodium phosphate and the gaseous nature of carbon dioxide, which allows easy excretion. This buffer action is a key to the stability of all living organisms – but, even more, it served to stabilize hydrogen ion concentrations in oceans and other waters. Henderson realized that water, with its extraordinary properties, together with carbon dioxide seemed uniquely fit to serve as the basis for all living systems (Edsall, 1973, p. 350).

Reflecting on this early work in "Memories," Henderson cited this as the point at which he became interested in the "fitness" of those substances for physiological processes (1936–9, p. 134). According to Cannon (1945), the discovery of the "extraordinary capacity" of carbonic acid to preserve neutrality had "far-reaching influences in Henderson's thinking." Henderson extended research into neutrality-maintenance capacity, which became a key element in his later work on physico-chemical systems (Cannon, 1945, p. 35).

In his report on Henderson's early work, younger colleague John Edsall noted that these "basic facts pointed clearly to a 'teleological order' in the universe." But Edsall immediately went on to indicate that Henderson "explicitly disavowed any attempt to associate this order with notions of design or purpose in nature, and considered his views fully compatible with a mechanistic outlook on the problems of biology" (Edsall, 1973, p. 350).

Henderson also credited John Theodore Merz' *History of European Thought in the Nineteenth Century* for its influence on the philosophical sections of the *Fitness* volume. Merz' four-volume study, with a whole volume devoted to the sciences, is fundamentally organismic in its outlook, and Merz was quite adept at identifying scientific and philosophical interactions (Henderson, 1936–9, p. 173).

Retrospectively, Henderson also identified a "eureka moment" that occurred on or about Washington's Birthday, 1912, while he was walking down the slopes of

Monadnock (a southern New Hampshire mountain) and thinking about the history of science course he was teaching. He recounted: ". . . it occurred to me suddenly, unexpectedly, and without any preliminary symptoms that I was aware of what I had been looking for in thinking about the fitness of the environment; [it remained] vivid and unforgettable" (1936–9, p. 175). It seemed to come together for him when he saw phosphate systems as very efficient buffers; he pondered the "usefulness of substances" and wondered whether "usefulness was an accident" (p. 177).

But to make sure that he would not be misunderstood, Henderson hurriedly assured his readers (and himself?) "that at this stage, I knew nothing of the literature of natural theology." Although he vaguely recollected William Paley and the watchmaker, he confessed that there was nothing in the history of thought "of which I was more ignorant and to which I was more indifferent." Having grown up in a period dominated by Darwin, he had known nothing of the *Bridgewater Treatises* (in which natural theology was explored at length by nineteenth-century scientists), and he had not been worried by the introduction of final causes into science. He was aware of, but not thoroughly knowledgeable about, the teleological literature and arguments (pp. 170–9).

By February 1912, however, having become fully convinced of the primacy of carbonic acid and water in the environment and the importance of the buffer concept, he set about writing *The Fitness of the Environment*. He claimed that he made no outline of the book (or of later ones, for that matter, including the treatise on *Blood*) and spent less than sixty days (and probably closer to fifty) writing the volume (p. 186).

In structuring his argument in *Fitness*, Henderson pointed to the Darwinian view of fitness as involving a mutual relationship between the organism and the environment and stressed the essential role of the environment as being of equal importance to the evolution of the organism. He opened his argument with the following paragraph:

> Darwinian fitness is compounded of a mutual relationship between the organism and the environment. Of this, fitness of [the] environment is quite as essential a component as the fitness which arises in the process of organic evolution; and in fundamental characteristics the actual environment is the fittest possible abode of life. Such is the thesis which the present volume seeks to establish. This is not a novel hypothesis. In rudimentary form it has already a long history behind it, and it was a familiar doctrine in the early nineteenth century. It presents itself anew as a result of the recent growth of the science of physical chemistry. *(p. v)*

His strong claim was that the actual environment is the fittest one possible for living organisms. Let me now locate Henderson's claims.

Locating Henderson's claims

Even as a sophomore at Harvard, Henderson confided in his "Memories" that he had "a vague feeling that there are not only many undiscovered simple uniformities behind the complexities of things, but also undiscovered unifying principles and explanations" (1936–9, p. 16). But there was more. Alongside this explanation, he recounted that he came upon William Prout's hypothesis (1815–16) concerning the periodic classification of chemical elements (all are multiples of the atomic mass of hydrogen) and felt the order involved must have an explanation. Was he retrospectively claiming that *he had himself become "fit"* to search for an understanding of the "fitness principle"? He was certainly willing to stray beyond the boundaries of the laboratory and the conceptual borders of the sciences.

By 1908, just as he was embarking on the construction of the fitness theory, Henderson began attending the philosophy and logic seminars of Josiah Royce in Harvard's Department of Philosophy. Through this channel, he came to know the works of Alfred North Whitehead, Bertrand Russell, and other contemporary philosophers. He continued to sit in on philosophy seminars in subsequent years. In the preface to *Fitness*, he generously acknowledged Royce: "His learning and generosity have in the past aided me to reach an understanding of the philosophical problems of science, and in the preparation of this book have repeatedly guided me aright" (p. xi). Royce himself had expressed belief in a form of universal teleology in his 1901 book *The World and the Individual*, and he enthusiastically called Henderson's work to the attention of other philosophers. In a long footnote at the conclusion of *Fitness*, Henderson cited Royce's teleological vision from the 1896 volume *The Spirit of Modern Philosophy* (Henderson, 1913, p. 311). The two joined with other Harvard faculty to discuss issues in the history and philosophy of science. These meetings went on for a full decade (1936–9, pp. 209–12; Parascandola, 1968, p. 71).

In his work, Henderson's ideas of fitness developed along with a growing interest in regulation of the physiological processes of the organism. Although he only later referred to this work, it was very much in accord with the concept of maintaining the *milieu intérieur* developed in the later decades of the nineteenth century by Claude Bernard and other contemporaries. (Henderson wrote a preface to an English translation of *Experimental Medicine* [Henderson, 1927] and made significant use of Bernard in setting out the problem he explored in *Blood: A Study of General Physiology* [1928]). But in his paper on the excretion of acids (1911), Henderson zeroed in on the seeming fitness of certain substances for physiological processes, pointing to the excretion of phosphoric acid as an indicator of renal action needed to maintain an acid–base balance: "There seems to be nothing in evolutionary theory to explain it and for the present it must be considered a happy chance . . ." (1911, p. 21; Parascandola, 1968, p. 73).

In "Memories," Henderson looked back and noted that he had questioned whether the role of carbon dioxide and phosphates was somehow linked in retrospect to special properties that made them more appropriate for physiological processes. As noted earlier, he located the moment at which the idea of the reciprocal nature of biological fitness came to him on Washington's Birthday, 1912:

> I saw that fitness must be a reciprocal relation, that adaptations in the Darwinian sense must be adaptations to something, and that complexity, stability, and intensity and diversity of metabolism in organisms could not have resulted through adaptation unless there were some sort of pattern in the properties of the environment that, as I now partly knew, is both intricate and singular. *(1936–9, pp. 177–80)*

His research focus became water, carbon dioxide, and other carbon compounds (see the bibliography in Cannon, 1945, pp. 52–3. At the level of theory, he looked for a single order that linked biological and cosmic evolution. (He addressed this latter theme at length in his second fitness book, *The Order of Nature*, 1917.) Was the explanation he sought mechanical or teleological? But teleology, as he used the term, was limited. There were *no final causes, no entelechy* (emphasis added). The "teleological principle" in his understanding was inherent in matter and energy. These natural phenomena have original principles "essentially not by chance." But Henderson was consciously agnostic and refused to seek or find religious links for teleology. (His aversion to religious thought went back to his boyhood and was described vividly in "Memories" [1936–9, pp. 31–3].) For Henderson, teleology stood in parallel to mechanism, not as a replacement for it. As he put it in the preface to *The Order of Nature*: "Beneath all the organic structures and functions are the molecules and their activities . . . [they] . . . have been moulded by the process of evolution . . . and have also formed the environment" (1917, p. iv).

Henderson was struggling not to be misunderstood, and he concluded his preface with a plea:[2]

> I beg the reader to bear this in mind and constantly to remember one simple question: What are the physical and chemical origins of diversity among inorganic and organic things, and how shall the adaptability of matter and energy be described? He may then see his way through all the difficulties which philosophical and biological thought have accumulated around a problem that in the final analysis belongs only to physical science, and at the end he will find a provisional answer to the question.

But misunderstood he was. At least he thought he was. His correspondence was filled with letters attempting to clarify and define teleology. I include a long excerpt from a letter to Paul Lawson (Henderson, 1918b) so that the reader can better understand what Henderson was attempting to achieve:

[2] He returned directly to this issue in his review of J. S. Haldane's *Mechanism, Life and Personality*, 1913, discussed later in this chapter.

It is a little difficult for me to reply to your remarks concerning my two books and the idea of teleology. My own opinion is that what I have said is considerably less philosophical than your interpretation of it. If you will look at a living organism, or at a watch, you will find that it possesses, like many other things in the world, a pattern. There is a certain peculiarity, however, about the pattern of the watch which resembles the peculiarity of the pattern of the living organism, and differs from the peculiarity of the pattern of certain other things possessing other well-marked patterns, such as, for instance, the orbit of a planet, or a geometrical figure. This seems to me to be an objective characteristic of the watch which we know to have been an excellent proof of the fact that the watch was designed. It seems to me also to be an objective characteristic of the organism, and, in the case of the organism, the current interpretation of explanations of it is that it is natural selection.

What I maintain is that there is a pattern in the ultimate properties of the chemical elements and in the ultimate physico-chemical properties of all phenomena considered in relation to each other. I do not mean to say that this pattern is exactly of the same nature as the pattern of the watch or an organism. Still less do I mean to say or to imply anything about design or mind. The only minds that I know are the minds of the individual organisms that I encounter upon the earth. But I feel perfectly justified, in spite of a certain unavoidable vagueness and ambiguity, in using the word "teleology" for the pattern in which I am interested.

The important thing to my mind is, nevertheless, not any doubtful talking about the proper name to discuss such a thing, but the fact itself. That is to say, the objective fact that the properties of the elements bear a certain very curious relationship to the process of evolution.

In *The Order of Nature*, Henderson's philosophical explorations came farther forward as he recounted the ideas of natural organization and teleology in a wide array of earlier authors from Aristotle through Descartes, Leibniz, Kant, Goethe, Bernard, Dreisch, J. S. Haldane, and Bosanquet. But the problem of reconciling mechanism in nature with indications of purpose was the way Cannon had set out the problem in his biographical memoir: There was indeed "a teleological appearance of the world . . . It is something that is real . . ." The solar system, meteorological cycle, and organic cycle seem to imply "a harmony which corresponds to an order in nature." As for Henderson's question "What is the mechanistic origin of the present order of nature?" the answer, Cannon suggested, "may be approximately solved by discovering, step by step, how the general laws of physical science work together upon the properties of matter and energy so as to produce that order" (1945, p. 38).

Henderson had already indicated in the closing pages of *Fitness* what he thought he had achieved and what limits he had set on teleology:

At length we have reached the conclusion which I was concerned to establish. Science has finally put the old teleology to death. Its disembodied spirit, freed from vitalism and all material ties, immortal, alone lives on, and from such a ghost science has nothing to fear. The man of science is not even obliged to have an opinion concerning its reality, for it dwells in another world where he as a scientist can never enter. *(1913, p. 311)*

But Henderson had struggled to reach this point in his argument. As he summed up his thinking, he again asked the question "What then becomes of fitness?" He had already banished all metaphysical teleology from science and was left to explore two possibilities: "An unknown mechanistic explanation" of both cosmic and organic evolution exists – or it does not. While Henderson found it hard to credit such an "unknown" explanation, he added, with the historian's eye, that before Darwin's enunciation of natural selection it was hard to imagine a mechanical explanation of biological fitness. Therefore, at the end of *Fitness* he warned: "We shall do well not to decide against such a possibility" (1913, pp. 305–6). But let me be clear. When Henderson was composing *Fitness*, he had rejected the then current theories of vitalism and that of a designer for nature; but he had insisted on maintaining the term "teleology," albeit adjusted as he saw "fit." Was there ambiguity in his text? Let us turn to Henderson's contemporaries for a response.

What did Henderson's contemporaries say about his work?

Henderson's two early books, *Fitness* (1913) and *The Order of Nature* (1917), were reviewed by contemporary scientists and philosophers. Their reception, not dramatic by any standard, gives a good indication of the role of his ideas. It is interesting to note that Henderson's "reflective" and philosophically structured presentations antedated his fuller theoretical-scientific volume on *Blood: A Study in General Physiology* (1928), which itself developed from a sequence of papers in the *Journal of Biological Chemistry*, entitled "Blood as a physico-chemical system," beginning in 1921 and concluding in 1931.

One of the earliest, but also the fullest, reviews of *Fitness* appeared in *Science* (the journal of the American Association for the Advancement of Science) in September 1913 by the physiologist Ralph S. Lillie, who was at the time teaching at Clark University and later taught at the University of Chicago. His opening lines set out his view: "This book is essentially a discussion of the nature and implications of organic adaptation, that is, of the relation between the living organism and the environment, but is written from an unusual point of view." Lillie took the time and space to follow Henderson through his argument chapter by chapter with the full identification of carbon, hydrogen, and oxygen and their unique characteristics "which make possible the production of living protoplasm." They demonstrate "the greatest possible fitness for life" Lillie (1913), p. 337.

But Lillie was not completely satisfied with the adaptive teleology that Henderson had developed. He noted the transfer of the conception of fitness from the organic to the inorganic environment, which thereby achieves the reciprocal nature of biological adaptation. However, Lillie countered that Henderson had not dealt in detail with the organism itself and the interrelation between organisms and the environment: