The Great Humus Debate

From von Liebig to the present, what humus is — and what it can do for farmers — continues to be debated

BY WILL F. BRINTON

ABOVE, LEFT: Liebig's discovery lab in Giessen: one of the furnaces designed for ashing soils and plants with his unique invention of the "five-bulb apparatus" to aid quantitative capture of CO_2 while trapping water.

ABOVE: Justus Liebig in 1820 as an ambitious 17-year-old chemistry student in Bonn, Germany, before going to Paris to study.

If there were ever two figures from history who should have crossed paths, it would have been Sir Albert Howard and Justus von Liebig. Despite living in different eras, they both approached the subject of soil humus with passion and skill, seemingly on opposite ends of the spectrum. However, a fresh look offers a different perspective, revealing insights into the inconsistencies in humus revolutions and the origins of organic farming.

Justus von Liebig (1803-1877) is widely recognized for pioneering the "Mineral Theory" — that the essential nutrients for plants are inorganic minerals. This theory contributed to the transition from traditional agricultural methods such as crop rotations and manuring to what is commonly referred to as "chemical farming." Liebig's influence is often criticized in contemporary organic farming literature, beginning with Howard. However, delving into Liebig's extensive body of work presents a challenge in discerning which ideas to embrace and which to question.

Sir Albert Howard (1873-1947) is widely thought of as the father of organic farming. Coming after Liebig, he occasionally expressed admiration for his work, characterizing it as a "great advance," "vast," and "illuminating," noting that Liebig was "a pioneer not only in science, but in practice." But in his later years, after returning to England from service in British India, Howard became outspoken in condemnation of Liebig's legacy, which had taken strong root in England. In an important way, Howard established the now well-worn contrast of "chemical vs organic" farming.

My insight into Liebig's work stems from reviewing a 99-year-old print edition of his influential work *Chemistry and Its Application to Agriculture and Animal Physiology* (*CAAAP*), originally published in German in 1840. That work propelled Liebig into an international figure. The historian Rossiter called it a "Liebig craze." I also examined Liebig's work *Natural Laws of Husbandry*, which he published 23 years later in 1863 as it seemed crucial to evaluate any departures from his seminal theories of 1840. Speculations have arisen suggesting that Liebig became more engrossed in the development of chemical fertilizers or that he adopted a more apologetic stance in his later writings. To check the accuracy of various English word usages, I matched several quotes in the English editions against the extensive German digital archive in the online Liebig Museum in Giessen.

An interesting example of wording issues is that Liebig used "manure" to replace the German word *Dünger* (fertilizer). This turned out to be very unfortunate since it led to confusing English expressions such as "mineral manure" and "artificial manure" — terms that persisted for decades. Liebig seemed careless when referring in English to "manure" since it is necessary to read carefully what type he meant; in some instances it is hard to tell. Liebig, for example, valued gypsum (calcium sulfate) as a general soil amendment but referred to the practice as "manuring with gypsum." Some things he called artificial manure, such as "bone dust," "rape cake" and "wood ash," would today be considered natural, if not certifiably organic.

Regarding Liebig's personal life, I referred to an essay by agriculturalist Sherry Wildfeuer, known for her 40-year publication of the biodynamic planting calendar in Kimberton, Pennsylvania. Wildfeuer's essay shed light on Liebig's financial struggles, despite his fame, as he had to support five dependents. This is perplexing until we read historian Andrea Wulf's recent research on 19th-century German philosophers. She describes that professors were compensated based on the attendance of their lectures, shedding light on Liebig's financial situation.

To contrast Liebig's work with the popular, organic views that relate to humus, I have used Sir Albert Howard's writings, such as a 1947 edition of *The Soil and Health*, first published in the U.S.A. by Devon-Adair with Rodale support. I also refer to Howard's germinal work *An Agricultural Testament*, first published 1940 in England. Finally, I reviewed earlier work by Howard and his wife Gabriella from their time as agricultural administrators in British Colonial India.

It's important to remember how turbulent early 19th-century Europe was in Liebig's time. Industrialization was on its initial rapid rise, predating modern science. Historian Sieferle highlights a fascinating point: the discovery of coal in England just before Liebig's time led to the freeing up of 2.5 acres of land for farming for each ton of coal extracted from the ground. This coincided with a decline in plague outbreaks, fueling unprecedented population growth, surpassing what today seems feasible. Liebig's work may have been just waiting to happen. The pivotal question emerged: would humus or artificial manure prevail in addressing agricultural growth?

The Humus Enigma

At the core of the ongoing debate surrounding Liebig lies his renowned and frequently referenced rejection of humus, prominently featured at the beginning of *CAAAP* in the pivotal chapter "Plant Nutrition and Carbon": "there is not a shadow of proof that humus exerts any influence on the growth of plants." This statement has been used by numerous individuals, including myself, to elucidate the disregard that chemical farming has shown for soil humus. However, upon conducting further research, I have come to believe that this statement is often, if not entirely, misrepresented.

Liebig's opposition was not directed at humus itself, as many have assumed, but rather at an earlier theory in chemistry advocated by predecessors such as Thaer (1752-1828) — a theory with even earlier origins. This perspective conceived of plant nutrition as akin to "plants consuming soil organic matter," like animals feeding on forage to acquire nutrients.

This early, intuitive concept from medieval Europe was subsequently reformulated as the so-called "humus theory," incorporating elements of early science to explain how plants

Albert Howard's "Indore humus" system was adapted to both dry and wet seasons, utilizing pits during dry periods and thatch roofs for protection during monsoon seasons. Remarkably, operations as extensive as 1,000 tons per year on a single estate were overseen with "no capital investment," relying entirely on manual labor provided by indentured workers.

absorbed humus from the soil in soluble form, providing carbon solely for plants. However, this notion presented a misleading alternative to the process of photosynthesis and the absorption of CO_2 from the air by plants — a concept not understood at the time.

How could humus be a lasting and stable part of soil fertility, but then also be soluble to enter plants? Early chemists before Liebig used alkali to dissolve humus, wherein the somewhat misleading name "humic acid" derives — i.e., precipitation of coagulates when adding acid.

Liebig asked if this was possible at scale — in other words, could soil humus supply all the plant aboveground biomass with carbon? He first questioned whether there is really such thing as soluble humic acid at all — a story in itself — but just in case, he determined how much humus dissolves in normal soil water to became something appearing to be humic acid; in other words, capable of being absorbed by plants. The many inherent contradictions Liebig investigated were not at all apparent to the general population nor most scientists of the time, given the very nebulous concepts of soil, mineral solubility, cohesion and particle functions that dominated Liebig's era.

Below is a key paragraph in which Liebig explains why this perspective on humus required correction:

The opinion that the substance called humus is extracted from the soil by the roots of plants, and that the carbon entering into its composition serves in some form or other to nourish their tissues, is considered by many as so firmly established that any new argument in its favor has been deemed unnecessary; the obvious difference in the growth of plants according to the known abundance or scarcity of humus in the soil.

Liebig goes on to explore the misconception surrounding humus from various perspectives. For example, he attempts to show how difficult it would be to account for the cycling of carbon between soil and plants using the humus theory, regardless of how soluble it may be:

Let us now inquire whence the grass in a meadow, or the wood in a forest, receives its carbon, since there no manure — no carbon — has been given to it as nourishment? And how it happens, that the soil, thus exhausted, instead of becoming poorer, becomes every year richer in this element? A certain quantity of carbon is harvested every year from the forest or meadow, in the form of wood or hay, and, in spite of this, the quantity of carbon in the soil augments; it becomes richer in humus.

Liebig's remark hints at his near grasp of photosynthesis, a concept not fully acknowledged until later in the century. While chlorophyll had been described by French chemists in 1818, its function beyond imparting greenness remained elusive. Liebig contributed to the pioneering research of French chemist Saussure (1767-1845), a key figure in early photosynthesis studies. Alongside Saussure and other chemists, Liebig established that plants absorb carbon dioxide and release oxygen, effectively "purifying dirty air." He correctly deduced that plants derive oxygen from decomposing water, yet significant gaps in understanding remained. Historians lament the nearly century-long delay in comprehending photosynthesis, potentially influenced by the entrenched belief in the incorrect humus theory.

Liebig certainly sparked a necessary crisis by debunking the old humus theory, yet he failed, perhaps inevitably, to replace it with the more comprehensive understanding we have today.

Liebig had already worked out that the assimilation of carbon required a series of chemical reactions that, starting from some organic acids, ended in the formation of sugar. The dilemma was that with photosynthesis not being fully recognized, where and exactly how, if not from the soil, did plant carbon compounds originate?

In 1845, the Scottish Botanical Society jumped into the controversy by studying if it was possible to transfer carbon from the soil to plants, as proposed by the humus theory. They reported:

On the hypothesis of organic matter being the sole food of plants, there must have been from these and other sources of transformation an enormous annual diminution of the quantity of organic substances in the soil ever since the commencement of *the present system of things; and it follows irresistibly that the two living kingdoms of nature could endure no longer than while the primitive store should withstand this annual demand upon it.*

This conversation sparked what could be considered one of the earliest serious attempts to calculate the amount of organic carbon stored in the Earth's reserves. The report continued:

Assume one-fifth of the [earth's] surface to be covered with soil to the depth of one foot; one-tenth, or ten percent of this soil to be organic matter, and three-fifths of this organic matter to be carbon. On these data, taken in round numbers, there could be nearly three billions and a half of tons [3,500 gigatons] of carbon in the organic compounds of the soil of such a portion of the earth's surface.

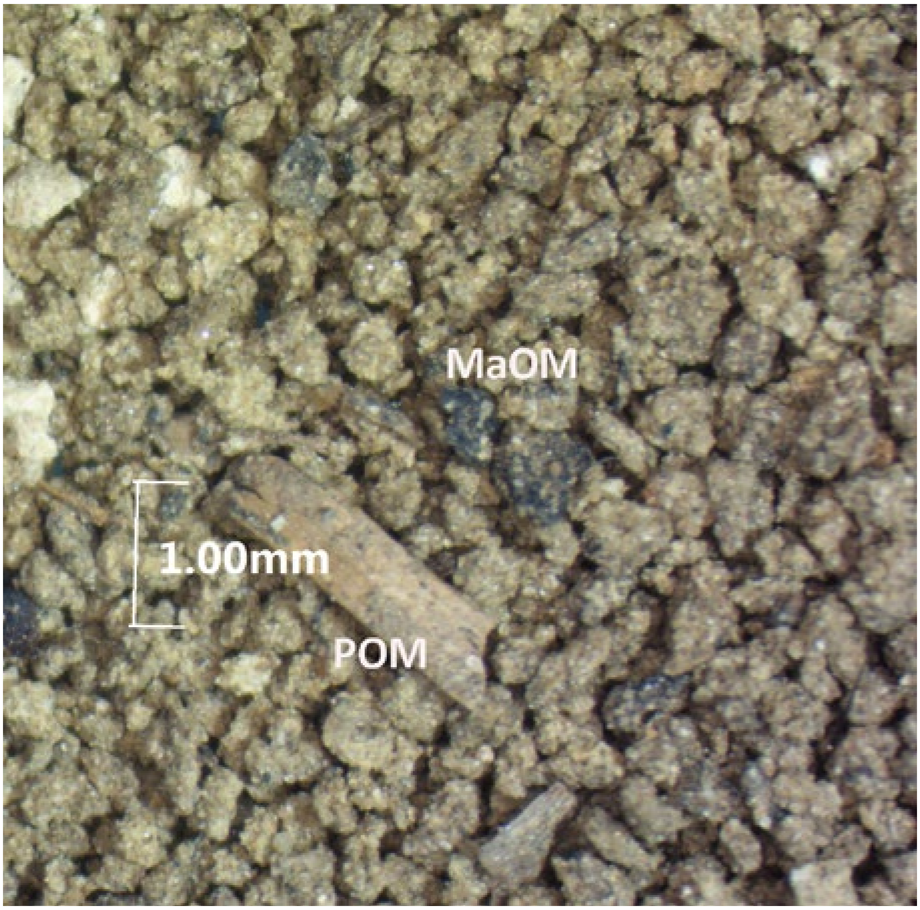
This early assessment of global soil carbon demonstrates remarkable precision by contemporary standards (the latest precise estimate is the earth has 3,300 gigatons of stored carbon). From this it was deduced that if the humus theory proved accurate, fulfilling the carbon requirements of plants would have resulted in the total depletion of all soil carbon on Earth within a span of merely 740 to 6,000 years, depending on factors such as soil depth.

The 20th-Century Humus Skirmish

The controversy surrounding the Liebig humus theory emerges when we erroneously juxtapose it with his initial assertion. This issue was further intensified during the formative years of organic farming in England by Sir Albert Howard, who frequently targeted Liebig on this matter, criticizing him as being "only half a man" for dismissing humus and advocating for the use of inorganic nutrients as a substitute.

It is important to highlight that Howard, in contrast to Liebig, was known for his work of over three decades of British colonial service in India from 1905 to 1933. His chief accomplishment, aside from being a very broad-minded agricultural advisor, was developing "humus manufacturing," which he called the "Indore Compost System" (named for the city in the Madhya Pradesh region in northwest India). This form of large-scale, manual composting of all farm and village wastes appears to have been taken from the Chinese Hunza tradition, which Howard had observed and recognized from F. H. King's 1911 classic *Farmers of Forty Centuries.* Furthermore, Howard proposed that crops should predominantly, if not entirely, rely on the resultant humus for growth, positioning him as a pioneer in organic farming principles (though it's worth noting that Howard didn't adopt the term "organic farming" until after its introduction in England by Lord Northbourne and Ehrenfried Pfeiffer).

Following the death of his wife and working companion, Gabriella, in India, Howard made a solemn vow to leave the field of agriculture. He returned to England in the mid-1930s and was knighted for his service. At the same time, he encountered a



After soil is sieved to 2 mm, POM and MOM are visible under a microscope as either larger pieces of organic matter (POM) or soil particles stained with organic matter (MaOM).

PHOTO COURTESY OF WOODS END LABRATORY

lively debate surrounding the industrialization of farming in England — a trend that had already begun in Germany in the 1920s via biodynamic farming, following the widespread adoption of Haber chemical nitrogen in agriculture. Intrigued by this debate, Howard reinvigorated his focus on humus, presenting it as a comprehensive alternative to chemical farming. His emphasis was so persuasive that British agriculturalist Hopkins remarked, "If Sir Albert Howard had not advocated for the exclusive use of humus in crop production, far fewer people today would even believe it to be necessary."

Howard had a rightful complaint when he wrote, "The ease with which crops can be grown with chemicals has made the correct utilization of wastes much more difficult." Every biological farmer knows this today. In an even earlier work, around 1927, on his composting methods from India, he commented, "you don't see chemical fertilizers in China or India" (the chemical revolution was yet to start there). Back in England, in an unfamiliar setting, Howard leveraged the popular misunderstanding of Liebig's rejection of humus to promote his own humus school. We do not know if Howard's composting methods could have worked in England at the time — I suspect not, since the method in India involved large amounts of readily available indentured labor. He would have had to convert this composting approach into a more capital-intensive process before chemical farming took over, and he died before any of this happened.

Looking back, it's easy to assign blame to Liebig — or to Howard. Nevertheless, it's also important to note that by the 20th century, unlike in Liebig's time, soil microbiology, nitrogen mineralization and nitrogen fixation had become well-established fields. These advancements shed light on areas that Liebig found perplexing, such as the microbial decomposition of humus to mineralize nitrogen (he believed it all had to pass through in ammonia form). Another example is nitrogen fixation, which was not understood at the time, leaving him puzzled by the exceptional performance of legumes in improving crop rotation, or why they needed so much calcium.

Howard continued to express disdain for Liebig's humus revision even after Selman Waksman of Rutgers published his influential work *Humus and Its Composition* in 1936. Waksman, who served as the department leader of my college advisor, Albert Schatz, both esteemed microbiologists and humus enthusiasts, thoroughly addressed the misconceptions surrounding the old humus theory in one chapter of his book, thereby supporting Liebig's perspective. Interestingly, Howard extensively cited Waksman's work in his own *An Agricultural Testament* in 1940, seemingly unaware of the contradiction.

The 21st-Century Defeat of Humus

The narrative doesn't conclude here. Humus has recently encountered a substantial new challenge, echoing Liebig's revolutionary skepticism. This challenge comes from two scientists, Kleber and Lehman, the latter renowned for the discovery of biochar. They argue that terms like "humus," "humic acid" and "humin," along with related terminology, are no longer suitable from a robust scientific standpoint and should be abandoned.

This startling revelation builds upon a suspicion Liebig had long ago: the conditions necessary for the formation of alkaline extracts, from which the term "humic acid" originated, do not occur naturally. It is now suggested that humic substances serve only as indicators of something else — namely, finely divided organic matter undergoing various stages of breakdown, conceptualized as a soil continuum model (SCM). From this perspective, humus, as traditionally understood, ceases to exist. Proponents of this view echo Liebig's sentiments closely when they argue in a *Nature* article that beliefs in humus and humic matter "not only hinder a better understanding ... but also lead to misleading conclusions."

This view challenges us to comprehend how decomposing organic matter in soil undergoes stepwise fragmentation by macro- and microorganisms into smaller particles that acquire dynamic characteristics. Drawing from previous terminology, the larger fragments are called POM (particulate organic matter). These fragments are visible, and studies have already shown that organic farming systems have a significantly higher presence of POM in soil compared to conventional methods.

Since the emergence of the SCM theory, widely accepted in the soil science community, the race is on to explain the much smaller pieces of soil organic matter and their apparent stability. The popular view is that the particles in a very tiny state interact dynamically with soil minerals, particularly clay, forming what is now called MaOM (mineral-associated organic matter). This concept resembles Waksman's original theory of "organo-mineral" complexes, developed nearly a century ago. In essence, the pieces of reduced organic matter are believed to be stabilized primarily by the protection afforded by soil minerals, rather than by their being synthesized humic-acid polymers.

As can quickly be grasped, this view places all soil organic carbon at risk for decomposition and total loss. This is a serious challenge, coinciding with the current high-stakes discussions surrounding soil carbon sequestration. It means that each farm may have to manage soil organic matter differently depending on soil structure.

It's impossible not to notice that this huge shift in humus perspective parallels another abrupt change, which is the recent reconsideration of Lehmann's biochar hypothesis. A team of scientists led by Lucas Silva from Oregon State University have recently unearthed compelling evidence that significant soil disturbances occurred in the Amazon basin, the exact cause of which remains unknown, dating back several thousand years before the presence of settlements and charcoal believed to be the cause of terra preta. This finding challenges the notion that indigenous settlers and their charcoal wastes were responsible for the creation of terra preta soils. From this fresh perspective, there's a growing consensus that the practice of "biochar," like humus, may need to be reconsidered — and perhaps abandoned. This abrupt shift underscores the increasingly rapid cycle of scientific paradigms in modern mechanistic research and practice.

We might ask: How can we rejuvenate soil humus when its nature remains enigmatic? Reflecting on the proverb "you can't manage what you don't understand," we should question: what function does compost serve? Howard referred to it as "humus manufacture," yet the latest perspectives suggest it only consists of various states of particulate organic matter, without genuine humus formation. With organic matter stabilization in soil now considered a flawed concept, the field of compost stability testing may undergo change.

Organic and biological farmers have embraced long-standing traditions and practices associated with soil and farm health. Their results consistently show increased soil organic matter levels, regardless of the specific definition employed. However, soil and compost labs may feel challenged to consider revising their methodologies to more accurately assess the status and progression of organic matter particles as they become stable components of soil fertility. ACRES

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