

Skin, Clothing, and Dwelling: Max von Pettenkofer, the Science of Hygiene, and Breathing Walls

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Abstract

Gottfried Semper is often credited with originating the concept of the building as skin in architectural theory, but an alternative trajectory of this idea can be found in the mid-nineteenth-century science of hygiene. In **Skin, Clothing, and Dwelling: Max von Pettenkofer, the Science of Hygiene, and Breathing Walls**, Didem Ekici explores the affinity of skin, clothing, and dwelling in nineteenth-century German thinking, focusing on a marginal figure in architectural history, physician Max von Pettenkofer (1818–1901), the “father of experimental hygiene.” Pettenkofer’s concept of clothing and dwelling as skins influenced theories of architecture that emphasized the environmental performance of the architectural envelope. This article examines Pettenkofer’s writings and contemporary works on hygiene, ethnology, *Kulturgeschichte* (cultural history), and linguistics that linked skin, clothing, and dwelling. From nineteenth-century “breathing walls” to today’s high-performance envelopes, theories of the building as a regulating membrane are a testament to the unsung legacy of Pettenkofer and the science of hygiene.

In his 1949 “Manifeste du Correalisme,” Viennese architect Frederick Kiesler challenged Le Corbusier’s famous dictum using a metaphor of the house as skin: “The house is neither a machine nor a work of art. The house is a living organism ... the skin of the human body.”¹ By declaring the house equivalent to the skin of the body, Kiesler used an organicist discourse that emphasized the environmental performance of architecture.

What is the history of such thinking about a building as an envelope like “the skin of the human body”? In the nineteenth century, the concept of the dwelling as a skin came out of a lively communication and cross fertilization among disciplines. Most important, it emerged from the science of hygiene in Germany where physician Max von Pettenkofer (1818-1901), “father of experimental hygiene,” conceptualized the dwelling as a skin that envelopes its inhabitants (Figure 1).² His theory of the dwelling as a skin falls under the rubric of scientific organicism, which focused on functionality based on empirical research in life sciences such as biology and medicine.³ As I will demonstrate, it was also informed by an emerging discourse in ethnography, linguistics, and cultural history on the affinity between skin, clothing, and dwelling. Around the same time that Pettenkofer developed his concept of the dwelling as skin, architect Gottfried Semper translated these ideas into architectural theory.

Hygiene, Physiology, and the Skin

Pettenkofer was trained in pharmacy and medicine in Munich and served as a chemist at the Royal Mint.⁴ In 1847, when he was just twenty-nine years old, he was appointed Professor of Medical Chemistry at the University of Munich. During his career in chemistry, he rose to fame through a series of discoveries, which included the development of a method to separate gold and silver, a process for manufacturing building cement that was as strong as Portland cement, and a method to preserve oil paintings. The latter two achievements made him well known in architecture and art circles. Pettenkofer later devoted himself to the emerging field

of hygiene and public health. In 1865, he became the chair of the new Hygiene Department at the University of Munich, the first of its kind at a German university. Fourteen years later, Pettenkofer established the first hygiene institute in Munich. Under his stimulus, the new science of hygiene developed rapidly as his students went on to teach at the newly founded institutes of hygiene at several European universities.

The emergence of hygiene as a discipline should be understood in the context of the nineteenth-century public health movement. Starting in the 1830s and 1840s, a growing number of middle-class reformers in Germany, Britain, France, and the United States raised public awareness of health issues. Their agenda included all aspects of urban design, from sewers and water supplies, to street layouts and the construction of healthy buildings. Hygienists, together with architects, engineers, and municipal leaders, demanded stronger regulations for new urban development. The house was a central focus of the hygiene and public health movement; in physician C. Francken's words, "Both the physical and moral health of a nation depended on its conditions of housing."⁵ Using scientific methods to map everyday environments, therefore, Pettenkofer and his followers established themselves as experts in sanitary domestic design.⁶

When hygiene first emerged as a new science, it was closely associated with physiology.⁷ The physiology of the human body dominated nineteenth-century scientific thought, providing visual theoretical models for the laws of life and mind. As art historian Barbara Stafford notes, in the nineteenth century, "the human body represented the ultimate visual compendium, the comprehensive method of methods, the organizing structure of structures."⁸ Pettenkofer called hygiene "applied physiology," defining it as the physiology of the environment beyond the human body, which included air, water, soil, clothes, and the house.⁹ He understood disease not as a process triggered in the body but as a process caused by the external dangers of infection in the environment.

In nineteenth-century physiology, the skin was considered to be one of the most vital human organs for health. The importance attributed to the skin stemmed from the miasmatic theory of disease, which focused on the role of the air as carrier of disease. Physician Hans Buchner explained the significance of the air:

We lead our lives in air as fish in water. It surrounds us from all sides. It provides us with necessary oxygen for burning and heat generation and absorbs the spent products via exhalation and perspiration as well as the generated surplus heat from our skin surface. In all these relations, the air represents a significant factor for our health.¹⁰

Buchner and his contemporaries regarded the skin as a regulating and protective barrier against the atmosphere.

The attention given to the skin in physiology points to a broader change in the perception of the body from the late eighteenth century onwards. Studies on the cultural history of the body have shown that a new delimited and individuated body model emerged during the Enlightenment. In his book *Rabelais and His World*, Mikhail Bakhtin describes how the onset of bourgeois modernity brought a gradual transition from a fluid to a closed body model.¹¹ Mechthild Fend has remarked that in the course of the eighteenth century, the skin developed into a site of exchange and interface that transmitted information. Around 1800, such terms as *surface* became prominent in medical discourse, and dermatology emerged as a new medical science based on reading the body surface as a signifier of disease.¹² As Claudia Benthien has shown, the skin gained semantic meaning that expressed health, disease, and inner character.¹³

Physiology shaped nineteenth-century hygienists' conception of the skin as an interface.¹⁴ They believed that the skin's functions included respiration, perspiration, heat regulation, and protection. The body regulated heat through radiation, conduction, and evaporation by transpiring through pores in the skin. The skin secreted toxic matter and

carbon dioxide through perspiration and absorbed oxygen, although in small amounts compared to the lungs. Pettenkofer stressed the importance of keeping the skin healthy, “because a vigorous skin stands atmospheric changes much better and protects against many diseases.”¹⁵ As the site of exchange, regulation and protection, the skin had to be washed, disinfected, ventilated, and kept at a healthy temperature. Hygiene manuals often included sections dedicated to the care of the skin in the same chapters where clothing was discussed, reflecting hygienists’ view of the close relationship between skin and clothing.¹⁶

Clothing and Dwelling in the Science of Hygiene

Physicians’ concern for the skin had a transformative effect on concepts of healthy clothing and dwelling. Pettenkofer was the first physician to link skin (*Haut*), clothing (*Kleidung*), and dwelling (*Wohnung*) explicitly. He started mapping the physiology of the body’s environment by assessing the air quality of occupied rooms. In an 1851 article, he focused on the permeability of walls:

If one wants to live comfortably and healthily, it seems to me equally necessary that one is surrounded with walls that are permeable to air up to a certain extent, as one is appropriately clothed only in fabrics that allow air flow. The pores of our walls can be as important as the pores of the epidermis of the body.¹⁷

Pettenkofer equated walls with clothes and skin in their permeability. For the skin to breathe, clothing and buildings had to breathe. He believed experiments on the permeability of construction materials were vital for the “science of building materials” and argued that construction materials for housing should be selected based on science rather than on builders’ intuition.¹⁸

In Pettenkofer's later works, the relationship between skin, clothing and dwelling came into sharp focus. In an 1858 speech, he identified clothing and dwelling as primary media through which the body controls the effects of the environment:

We moderate and change the effects of the atmosphere on us through clothing [*Kleidung*] and dwelling [*Wohnung*]. Both serve towards the same purpose: to maintain a consistent exchange with the atmosphere. In no sense, are they meant to block such an exchange, but to limit it to the necessary levels. We can call our clothing a house [*Haus*] that we carry around with us, and our dwelling a wide dress [*Gewand*] in which we walk around. The nomad tent, so to speak, is half way between a cloak and a house.¹⁹

Pettenkofer used “dwelling” interchangeably with “house” in his texts. He equated dwelling with clothing based on the main function of both, which involved acting as surrogate skins.

Pettenkofer asserted that clothing would be a valuable study topic for physiology and clinical medicine if clothing could serve as an envelope, partially taking over the functions of the natural body surface.²⁰ To that end, the main purpose of clothing was physiological—namely, the regulation of heat flow from the body—and its social, moral, political, and economic functions were secondary. Ideally, clothes should allow continual ventilation of the skin while keeping the body warm. In the 1860s, he conducted the first experiments on clothing to determine heat capacity and porosity of various fabrics.²¹ Following Pettenkofer, clothing reformers and hygienists reiterated the importance of permeable clothing made of cotton and woolen fabrics. Underwear and other types of clothing designed to allow the body to breathe were widely advertised in reformist publications (Figure 2).

Having stressed the physiological function of clothing, Pettenkofer warned that “form or fashion should never be a major consideration, and the tailor should not to hold his scissors like a scepter above the sanitary purposes of dress.”²² He extended this utilitarian argument to

architecture: “Yet at the expense of functional imperatives, not only the tailor, but also the architect now and then indulges himself in ornament.”²³ He was not alone in equating ornate clothing to architectural ornament. As architectural historian Alina Payne has shown, nineteenth-century publications made no distinctions among the manifestations of ornament in architecture, decorative arts, and apparel.²⁴

Pettenkofer concluded that the inquiry into the physiological functions of clothing and dwelling would culminate in the development of new forms that would look as different “as a turbine compared to an overshot waterwheel,” but that “people will eventually learn to appreciate the innate beauty of these forms.”²⁵ Pettenkofer’s physiological view of the dwelling aligned with materialist explanations in architectural theory that equated new forms to new materials and technologies.²⁶ Presaging Louis Sullivan’s famous motto, “Form follows function,” Pettenkofer declared in 1873, “The understanding of functions determines external forms...”²⁷ The dictum that form follows function originated with French biologist Georges Cuvier (1769-1832) in his scientific version of organicism based on empirical research. Cuvier claimed that the function of an organ, appendage, tissue, or other body part dictates its form.²⁸ This dictum became a guiding principle of functional morphology, which later in the century influenced not only Pettenkofer’s concept of clothing and dwelling as surrogate skins but also Gottfried Semper’s 1851 typology of architectural form.²⁹

In March 1872, Pettenkofer gave three public lectures at the Albert Society in Dresden on the relationship of the air to clothing, dwelling, and soil. These lectures were widely publicized and were later published in book form (Figure 3).³⁰ The first lecture was on clothing and the second on dwelling. In his second lecture, Pettenkofer revisited the theme of permeability of walls. He claimed that the dwelling functions like clothing, protecting the skin and facilitating the exchange of toxic gasses for fresh air. Reiterating his analogy between the cloak and the tent, he also considered the hat equivalent to the roof and the roof

the headgear of the house. He argued that the house should be subject to the same hygienic rules as clothing and the materials used for houses should have the same permeable qualities as those used for clothing:

Walls allow air to pass through them, and they must do so to a certain degree, if we are to preserve our health within them with some comfort and without injury. Current opinion is certainly opposed to my assertion about the permeability of walls to air, even more so than to that about the permeability of our clothing.³¹

By advocating permeability, Pettenkofer challenged common views about the separation of the house's inside and outside. "In speaking of our clothes," he wrote, "the well-being of our body requires a continuous current of air to flow round us, and for the same reason a flow of air must take place continually from the open air through our dwellings."³² In his view, walls should no longer be solid barriers; rather, they should facilitate exchange with the outside. Pettenkofer did several experiments to test the porosity of building materials. To demonstrate the porosity of brick, he pumped air through a solid brick cylinder that was sealed on the sides and unsealed on both ends; the air extinguished a candle flame at the end (Figure 4). Physicians and building experts later cited this experiment as proof of the action of natural ventilation through walls.³³ What Pettenkofer and his followers overlooked, however, was the fact that the maximum natural air pressure across a wall is much lower than the pressure required to extinguish the candle's flame in the experiment. In the decades following the publication of the experiment, Pettenkofer's ideas on the porosity of walls transformed the construction of houses, although his hypothesis was scientifically discredited in the 1920s. In fact, the myth of "breathing walls" continues to be repeated today.³⁴

The concern for porosity led to an increasing interest in building materials and their behavior. Physicians studied fabrics and building materials in terms of their *Porenvolumen*

(volume of pores), which was seen as a determining factor in their heat capacity, porosity, and water intake (Figure 5). They promoted porous materials such as burned clay brick, limestone, and sandstone as the best options for house walls above ground level because their air content made them “good dry insulator[s] and a poor heat conductor[s].”³⁵ Hollow bricks were also favored for their thermal qualities.

Based on the requirement of porosity, hygienists employed the metaphor of dress for the dwelling. In his 1882 book *Die gesunde Wohnung* (The Healthy Dwelling), physician Moritz Alsberg cited Pettenkofer’s experiment with the brick cylinder and the candle and warned against the health hazards of a humid dwelling:

The dwelling [*Wohnung*] is in a sense our most expansive dress [*Kleid*], and just as wet clothes worn too long suppress the skin activity and cause many health disorders, so a damp dwelling can be just as harmful to health when it prevents perspiration, impairs the metabolism and thus causes illness sooner or later.³⁶

With the dress metaphor, Alsberg stressed the importance of well-ventilated, dry domestic spaces. In hygiene publications, physicians often pointed to the link between dampness of houses and high mortality rates. Arguing for larger windows in residential spaces, Alsberg called windows “the lungs of a dwelling.”³⁷ If porous walls were the skin of the house, windows were its lungs.

By the beginning of the twentieth century, the metaphor of the dwelling as clothing was widely used in popular literature on health and hygiene. In his hygiene manual, after discussing clothing, physician August Gärtner defined the dwelling as shelter and protection from the elements, adding that it was for the family what dress was for the individual.³⁸ Physician Anna Fischer-Dückelmann wrote in her popular 1901 household handbook *Die Frau als Hausärztin* (The Woman as Family Doctor): “Over our bed, our clothing for the

night, stands another large shell, our dwelling. Its main principal is identical to our dress and bed: it must be porous; inhale the outdoor air and exhale the indoor air.”³⁹ The clothing metaphor went hand in hand with the myth of “breathing walls.”

Breathing Walls

Architects adapted the theory that equated clothing and the dwelling from physicians. In his 1894 book, for example, architect Lothar Abel referred to Pettenkofer to argue for the sanitary advantages of porous building materials. “Professor Pettenkofer has shown in his experiments that the walls of a house built from porous materials facilitate ventilation and bring about an exchange of gases between the living areas and the outer atmosphere, letting the foul air of the room out and fresh air in.” He then quoted Alsberg’s assertion, “The dwelling is in a sense our most expansive dress...”⁴⁰ The clothing metaphor underlined the importance of using porous construction materials that would allow natural ventilation through walls.

An increasing interest in the performance of the building skin paralleled the attention to materials. Physicians advocated construction of double skin external walls with air circulation between the layers to ensure that the inner layer remained dry and at constant temperature. In addition to their insulating qualities, such walls were praised because they facilitated the installation of artificial ventilation and heating ducts⁴¹ (Figure 6).

In the early twentieth century, several wall designs that facilitated air circulation emerged. In 1909, architect Heinrich Tessenow designed the “Tessenow Wall” for residential construction, a standardized hollow wall that allowed continuous air circulation between the inside and the outside of the house (Figure 7).⁴² The Tessenow wall was composed of two layers of brick around timber members placed vertically.⁴³ The timbers formed uninterrupted,

vertical airtight canals. At meter intervals, the lower ends of the timber canals opened to the room, and the upper ends opened to the attic, thereby promoting ventilation.⁴⁴

At the 1911 International Hygiene Exhibition in Dresden, Christoph & Unmack Company displayed a dismountable and transportable wooden weekend house called the Breathing House (Figure 8). The house was part of the company's prefabricated Döcker Buildings line, which had originally been built by Danish cavalry captain G. H. C. Döcker as hospital barracks and had expanded to include military barracks, Red Cross pavilions, and houses. Company brochures stressed the hygienic aspects and advanced ventilation of the houses, in which all the inner surfaces were clad with washable materials.⁴⁵ They were insulated against heat and cold by air ducts inside the walls and employed double roofs and double floors. The Breathing House utilized the Schreider Ventilation system, named after its inventor George Schreider (Figure 9). "A draft free intake of fresh air is accomplished via the shortest route and the room is thoroughly purged with self-heated fresh air. The used air and dust are eliminated through a vent on the roof without disturbance to breathing organs."⁴⁶ The house had a respiration system analogous to that of the human body, by which the air was continually circulated and purified.

The ventilation systems of the time were directed toward purifying the air inside buildings. The Hygiene Exhibition included a section devoted to "ventilation and heating" that featured graphic representations of heat and carbon dioxide discharge from people and the deterioration of air quality through exhalation and perspiration; it also offered data about the necessary ratio of air exchange in a room. Pettenkofer was still an influential figure in the field, and the exhibition presented his method of measuring carbon dioxide in a room.⁴⁷ Models demonstrated the porosity of building materials and mechanisms that were designed to measure carbon dioxide and filter and disinfect air. Air filters that could be placed inside walls were claimed to "filter air of all impurities and also to a large degree of

microorganisms”⁴⁸ (Figure 10). These apparatuses reflect the desire to create building walls that would act like the human skin, serving as regulating barriers against the atmosphere. Walls, like the skin, would “breathe,” facilitate exchange between internal and external space, adjust temperature levels, and protect against microorganisms and impurities in the atmosphere.

The obsession with purifying and regulating air through mechanical means also informed later modernist architecture. In 1935, Le Corbusier developed a similar concept, which he christened “exact respiration,” whereby a “neutralizing wall” enveloping the building regulated the indoor climate. Indoor air was continually circulated, “freed of dust, disinfected, humidified and brought to a constant temperature” to be readily consumed by the lungs.⁴⁹ In other words, the neutralizing wall “breathed.” Le Corbusier explained the need to provide “exact air” in buildings by citing statistics about the importance of respiration from a medical physiology textbook.⁵⁰ His lengthy references to that book show the extent to which medical thinking shaped Le Corbusier’s concept.

Nineteenth-Century Discourse on Skin, Clothing, and Dwelling

Although physiology shaped Pettenkofer’s understanding of the dwelling as a skin, it was not his only source for the analogy. Pettenkofer’s concept of the dwelling as a projection of both skin and clothing had already been introduced in Germany in the intersecting fields of ethnology, *Kulturgeschichte* (cultural history), and linguistics.⁵¹ A scholar of wide ranging scientific pursuits, Pettenkofer had a lifelong interest in ethnology and linguistics.⁵² In 1870, he became a founding member of the Münchener Gesellschaft für Anthropologie, Ethnologie und Urgeschichte (Munich Association for Anthropology, Ethnology and Ancient History), the Munich branch of the German national association.⁵³ Physiologist Johannes Ranke presided over the Munich association, and physicians and medical academics besides

Pettenkofer were among its founding members.⁵⁴ It published its own journal and members met once a month to give papers and present their latest research.

Pettenkofer did not engage in anthropological or ethnological research, but his analogy between clothing and dwelling had ethnological connotations. To prove his analogy, he gave the example of the nomad tent, which he described as “half way between a cloak and a house.”⁵⁵ Ethnologist Gustav Klemm (1802-67), the director of the Royal Library in Dresden, had used the nomad tent to exemplify the close relationship between clothing and dwelling.⁵⁶ In his ten-volume, *Allgemeine Cultur-Geschichte der Menschheit* (Universal Cultural History of Humanity, 1843-52), Klemm undertook a systematic study of racial physiognomies, costumes, dwellings, tools, and artworks of societies based on the travel accounts of ethnologists and missionaries.⁵⁷ Although he had never travelled farther than Italy, his colossal project vividly portrayed the everyday environments of humans across time and geography. His aim was to provide a coherent narrative of development by categorizing human societies within a cultural-evolutionist framework.⁵⁸

Klemm’s *Allgemeine Cultur-Geschichte* was central to the field of *Kulturgeschichte*, which had developed in the late eighteenth century and focused on commerce, literature, religion, and science.⁵⁹ In his massive work, Klemm broadened the concept of culture to encompass all human activities and even the most trivial artifacts. “We analyze first the immediate surroundings of man, then the qualities that have been bestowed on him by climate and the external world... In this way, we hope to identify the cultural conditions in which people live in various regions, according to the different resources available to them through climate and natural environment.”⁶⁰ He examined the cultural objects of everyday life including body adornments, clothing, household items, and domestic architecture as expressions of a society’s collective spirit and its age. He categorized them to correlate race, climate, environment, technology, and art.

In his analysis of primitive bodies, Klemm highlighted the function of the skin as protection against the environment, echoing the common physiological view of the time. Klemm argued that in primitive societies, clothing developed as a protection against the atmosphere to support and enhance the function of the skin.⁶¹ Along with the use of language and fire, clothing differentiated humans from animals. According to Klemm, “The more man distances himself from the state of the animal, the more he covers his body.”⁶² The indigenous peoples on the lowest levels of culture did not have clothes, their healthy skin was their only protection. As an example, Klemm discussed the forest Indians of Brazil who had no clothing or dwelling, only a roof to protect against the sun’s rays. Equating the functions of clothing and dwelling, he pronounced, “Everywhere in the world, the dwelling is actually just an enlarged, expansive dress or an enhancement and extension of dress.”⁶³ With this statement, Klemm made a leap from a specific condition to a global understanding of dwelling as a form of dress. Elsewhere, he claimed that the nomadic cloak represented a tent and that in polar regions, where natives did not wear cloaks, the winter hut was used as a cloak (Figure 11).⁶⁴ Other contemporary texts linked clothing and dwelling in their primal function as protection from the elements.⁶⁵ While clothing and dwelling were substitute skins that enhanced the protection of the body against the elements, the opposite could also be true. Klemm viewed the painted skin as surrogate clothing. In his account, dense painting on the skin partially fulfilled the function of clothing by protecting the body against insects.⁶⁶

Pettenkofer’s concept of clothing and dwelling as a series of skins incorporated ethnographic ideas, while Klemm’s work responded to the discourse on hygiene. In an 1865 article on the function of clothing, Pettenkofer, like Klemm, turned to examples from “primitive” cultures to link skin, clothing and dwelling. He traced the origins of the human impulse to adorn clothes and house to “the tattooed savage who is naked in his battle against the environment.”⁶⁷ Then he issued a caution, implying the need to control this primal urge in

the “civilized man”: “We must never forget that form or fashion should never gain dominance over function...”⁶⁸ This idea of ornament as a primal instinct corresponded to Klemm’s assertion that body paintings and tattoos were expressions of the earliest art impulse, which subsequently found expression in tools, weapons, vehicles, and dwellings ⁶⁹ (Figure 12).

Klemm contrasted the adornments of primitive bodies with the hygiene of civilized bodies. Unlike the painting or tattooing of bodies, “the best adornment in our culture,” he pronounced, “is cleanliness, the dispelling of dirt from our bodies and immediate environment.”⁷⁰ For Klemm, cleanliness was a cultural criterion; in higher levels of culture, the cleanliness of the skin replaced its adornment. He stressed, “A basic medium to maintain health in warm and humid climates is cleanliness, to keep away insects from the skin and dispel dust and mold from skin pores.”⁷¹ Klemm’s arguments reflect contemporary practices of cleanliness and theories of clean skin that had been in circulation since the late eighteenth century.⁷²

Klemm’s and Pettenkofer’s moral stance against ornament would become one of the hallmarks of modernist architecture, exemplified by Adolf Loos’ well-known 1910 lecture “Ornament and Crime.”⁷³ Loos launched his famous attack on ornament using the figure of the Papuan who “tattoos his skin, his boat, his paddles, in short everything he can lay hands on.” This was natural to the Papuan as Loos declared, “The urge to ornament one’s face and everything within reach is the start of plastic art.”⁷⁴ However, it would be a symptom of degeneracy in the modern adult. Equating bodily ornamentation with ornamentation in all realms of culture, Loos remarked, “The evolution of culture is synonymous with the removal of ornament from objects of daily use.”⁷⁵ Echoing Klemm, Loos considered ornament as a marker of cultural evolution.⁷⁶

Like his nineteenth century predecessors, Loos made no distinctions among clothing, architecture, and everyday objects in regard to ornament. He criticized ornament in contemporary women's clothing as a sign of cultural regression, and he praised English gentlemen's unostentatious style of dress for its inconspicuousness, which was suited to modern life.⁷⁷ According to Loos, the same principle applied to the house facade, for buildings should fit modern man like an unpretentious suit (Figure 13). His ideas aligned with Pettenkofer's view of ornament as a primal urge that endangered function in modern clothing and architecture. In another article, Loos claimed that cleanliness came before art in producing a higher standard of culture and declared the plumber "the pioneer of cleanliness" and "the quartermaster of culture."⁷⁸ Loos's distaste for ornament on modern skin, clothing, and architectural facades is a testimony to the impact of the cross fertilization of ethnology, hygiene, and architecture in the nineteenth century. The lively dialogue among those disciplines, with its evolutionary connotations, shaped modernist architects' obsession with cleanliness in both physical and aesthetic senses.

Clothing and Dwelling as Prostheses

The affinity between skin, clothing and dwelling that emerged in ethnology was corroborated by linguistic analysis. During the early nineteenth century, ethnology received a powerful boost from linguistics, which analyzed language families along with ethnological grouping of peoples. Like ethnology, linguistic analysis focused its classificatory gaze on the human body and objects of material culture to uncover primordial patterns.

Two articles with the same title, "Haus, Kleid, Leib" (House, Dress, Body), published in 1848 and 1859, demonstrate how linguistic analysis linked skin, clothing and dwelling. The authors, both cultural historians and linguists, analyzed the etymological roots of similar-sounding terms for body, clothing, and house, and claimed that these terms were derived

from the same roots. The author of the first article, Wilhelm Wackernagel, gave examples that he believed proved the links between the words, including *gards* (yard) and *gurt* (belt); *camisia* (shirt), and *camera* (chamber); and *casa* (house), *hosa* (trousers), and *casula* (little hut, vestment). Similarly, he found that *kleid* (dress) and *glêt* (reed huts) were derived from the medieval word, *clêda* (wickerwork). Wackernagel concluded “Dress is therefore a house of the body. Even closer to the person is the body itself, which is again understood and named as a house, as a dress of the soul or the divine spirit.”⁷⁹

The author of the 1859 article, Ludwig Tobler, relied on Wackernagel’s essay heavily. After citing that work at length, he wrote:

In the course of cultural history, the dwelling [*Wohnung*] and clothing [*Kleidung*], the oldest needs of men, always evolved in parallel, contingent upon climate and prosperity. ... Certainly, in the deepest level of consciousness, ... the dwelling is experienced, so to speak, as an enlarged dress [*erweitertes Kleid*], clothing as a tight-fitting dwelling [*enger anliegende Wohnung*] of the body, just as the simplest indispensable tools appear to us as the replication, perfection, and substitution of the body organs. But more important, the parallel goes even deeper...the body seems to be to the soul what the dwelling and clothing are to the body.⁸⁰

According to Tobler, the boundaries between the body, clothing, and dwelling are blurred at an unconscious level, and clothing and dwelling are experienced as what I consider prostheses. Tobler’s analysis of the body focused on its own boundary, the skin. He referred to modern physiology, arguing that the skin was composed of cell tissue, fibers, and nerve cords and knots that cladded the inner body parts; further, man extended the fabric of his flesh through woven substances, overlaid skins, and furs.⁸¹ Hence clothing could be

considered like a second skin, and, conversely, the skin was a form of clothing because it could be conceived as the first cover of the body. He supported his claim with an old German saying, "the skin is closer than shirts."⁸² Tobler claimed there was a similar etymological affinity between *Haut* (skin), *Kleid* (dress), *Haus* (house), *Huette* (huts), *Heim* (home), and *ham* (the obsolete spelling of home). This affinity was most visible in the earliest dwelling, the tent made of skin and fabric, which made it the form of a house closest to clothing.⁸³

Tobler's concept of clothing and dwelling as "the replication, perfection, and substitution of the body organs" resurfaced in Ernst Kapp's philosophy of technology. In 1877, Kapp argued that "man unconsciously transfers the form, function and proportion of his bodily structure to the works of his hand." He called this process *Organprojektion* (organ projection).⁸⁴ His concept was based on analogies between organs and mechanical tools.⁸⁵ The human works produced by organ projection included costume and architecture, which emerged from the primal instruments for protecting the body, *Bekleidung* (dressing), and *Behausung* (habitation).⁸⁶ Kapp asserted that in its most primitive state, *Körperbedeckung* (body cover) could be described as a "portable dwelling," and he pointed to the etymological link between *Gewand* (dress) and *Wandung* (wall).⁸⁷

Representational arts, Kapp remarked, "expanded the concept of costume from clothes that wrap the body to everything the body wears, including the hand-made furnishings of the living space and the nearby surroundings."⁸⁸ To illustrate his argument, he borrowed two images from Theodor Wittstein's 1874 book *Der Goldene Schnitt und die Anwendung desselben in der Kunst* (The golden section and its application in art), which depicted the golden section applied to female and male clothing; he also referred to Hermann Klencke who had analyzed the golden section in clothes in his 1869 book *Kosmetik* (Figure 14).⁸⁹ German psychologist Adolf Zeising also influenced Kapp's ideas on Golden Section.⁹⁰ Zeising saw the most perfect realization of golden section in the human figure and applied it

to works of art and architecture, such as the Parthenon.⁹¹ For Kapp, the presence of the Golden Section in the body, clothing, and architecture proved his *Organprojektion* theory—that is, that man transferred the organizing principle of his body to the works of his hand. Kapp quoted from the work of art historian August von Eye, who reiterated Klemm’s argument that “room, chamber, house, and garden form an extension, an expansion of our clothes.”⁹² By the 1870s, understanding of the dwelling as an extension of clothing had spread beyond ethnology, linguistics and physiology to art history and philosophy.

Semper on the Skin and the Urges of Dressing and Adorning

Somewhat earlier, architect Gottfried Semper (1803-97) had introduced theories about the affinity between skin, clothing, and dwelling into architectural theory. As Harry Mallgrave has shown, Klemm’s studies influenced Semper’s thinking at a time when he took an increasingly ethnological approach.⁹³ The two men’s paths might have intersected when they were both located in Dresden, from 1834 until Semper’s exile in 1849.⁹⁴ Semper’s ethnological method shaped his quest to uncover the basic motives underlying the creation of art and architectural forms, which he found in handicrafts. Semper took an active interest in linguistics, which shared ethnology’s interest in tracing the roots of material culture. In the introduction to *Style in the Technical and Tectonic arts, or, Practical aesthetics*, his seminal 1860-63 book, he defined art as a language of “formal types and symbols” and predicted that linguistic research into the etymologies of words would reveal the evolution of forms in art and architecture.⁹⁵

Semper linked skin, clothing, and dwelling through the basic human urges of dressing (*Bekleidung*) and adorning. He first developed the principle of *Bekleidung* in *The Four Elements of Architecture* (1851).⁹⁶ From a primitive architecture, he derived the four elements—the hearth, the roof, the enclosure, and the embankment. The enclosure originated

from textile crafts; interwoven mats and carpet walls preceded durable walls by forming vertical enclosure in ancient dwellings. Such use of weavings for spatial enclosure also anticipated the art of dressing the naked body.⁹⁷ In other words, primitive architecture was the earliest form of clothing. Semper supported his claim by pointing out to the common root of the terms *Wand* (wall) and *Gewand*.⁹⁸ As textile hangings gave way to more durable walls, he argued, painted and paneled wall dressings imitated the textile style of the early walls.

Semper further developed the principle of *Bekleidung* in *Style*, where he traced the genealogy of architectural form back to textiles. In the first volume, dedicated to textiles, he argued that “the beginning of building coincides with the beginning of textiles.”⁹⁹ He believed that in primitive architecture it was not the structure but the woven materials that defined space “as a means of dividing the ‘home’, the inner life from the outer life.”¹⁰⁰ Once again, he turned to etymological analysis to show the textile origins of building elements, evidenced by such terms as *Decke* (cover, ceiling), *Bekleidung*, and *Zaun* (hedge, fence), which is similar to *Saum* (hem, fillet).¹⁰¹

Semper’s *Bekleidung* principle corresponded to the basic need to shelter the body. Similarly, Semper regarded adornment (*Schmücken*) as a basic human urge, the primitive manifestation of which is seen on the skin as body paintings and tattoos.¹⁰² Semper’s concept of adornment allowed him to conceptualize the human skin as a surface where all arts emerged. In his analysis of ancient textile arts, he examined the human skin first.

Without a doubt, the first natural product to be considered here is our own hide or human skin. The remarkable cultural-historical phenomenon of painting and tattooing the skin is also of great interest for the history of style. We do not really know whether the painted or etched lines and scrolls with which people who go partly or entirely naked almost universally decorate their skin represent the earliest of all decorative arts.¹⁰³

In the following paragraph, he cited Klemm, referring to his claim in *Allgemeine Cultur-Geschichte* that the tattoos of so-called savage peoples were derived from the “location and functioning of the muscles under the skin,” which evidenced their grasp of the structural and symbolic sense of ornament.¹⁰⁴ By rendering the body’s structural contours visible on the skin, tattoos became the earliest structural-symbolic art form. Elsewhere, Semper referred to the body paintings and tattoos of New Zealand and South Sea Islands peoples, ancient Assyrians, Egyptians, and Greeks to trace surface ornament in their objects and buildings to the art of tattooing.¹⁰⁵ He likened the painted or tattooed lines on the skin to “the thread as the linear element of textile surfaces.”¹⁰⁶ In other words, linear skin adornments signaled the generative process of weaving textiles. With the invention of weaving, ornament was transferred from the body surface to woven materials and, later, to more durable materials.

Semper’s and Klemm’s reading of the tattooed skin as a site that communicated the body’s inner structure corresponded to physicians’ earlier theories regarding the skin as a signifying surface. Semper did not discuss issues related directly to hygiene, but he was aware of some of Pettenkofer’s wide-ranging studies. For example, in the second volume of *Style* published in 1863, he cited Pettenkofer’s rediscovery of the production process of the ancient haematinum, a hard opaque red glass.¹⁰⁷ Semper might have encountered Pettenkofer’s work through his publisher Friedrich Vieweg, who published *The Four Elements of Architecture* and lectures by Pettenkofer, such as the 1858 lecture in which he referred to clothing as “a house that we carry around with us” and to dwelling as “a wide dress.”¹⁰⁸ While both Semper and Pettenkofer linked skin, clothing, and dwelling to fundamental urges of dressing and adorning, Semper diverged from Pettenkofer’s emphasis on function by stressing human creativity as the most important factor in understanding the evolution of architectural styles.¹⁰⁹ In other words, although Semper discussed architecture’s

textile origins, he did not equate dwelling with clothing or skin, as he did not view architecture solely in functional terms.

Conclusion

Under the influence of physiology and hygiene, architectural understanding of a building's periphery shifted profoundly. Physiological theories about the skin shaped nineteenth-century hygiene's view of clothing and dwelling as media through which the body can mitigate its relationship to the environment; in turn, these ideas had an impact on the way architects regarded the shell of a building. Pettenkofer's concept of the dwelling as a skin allowed architects to perceive the boundary between interior and exterior in more ambiguous terms. Pettenkofer saw walls not as solid barriers that protected inhabitants from the elements but as porous interfaces that mediated exchange between interior and exterior. Hygienists, building professionals, and social reformers understood architecture as an extension of the individual that mediated exchange with the environment. Such projects as the Breathing House became prosthetic aids for maintaining the health of the body.

In the late nineteenth and early twentieth centuries, physicians, architects, art historians, ethnologists, linguists, and philosophers developed the discourse on skin, clothing, and architecture. "The dwelling as an expansive dress" became an often-repeated trope that not only stressed the physiological function of clothing and dwelling but also portrayed them as unique expressions of culture and character.¹¹⁰ As Alina Payne has shown, costume came to be considered part of the decorative arts and part of the "culture of the house," conveying an implicit continuity linking clothes to household items to domestic architecture.¹¹¹ Modernist architects such as Adolf Loos relied on this continuity when they railed against ornament, tapping into the cultural evolutionary discourse developed by Klemm and Pettenkofer.

The fantasy of remaking architecture as skin is once again a theme in contemporary architecture.¹¹² Digital technologies, advanced building materials, and complex systems with real-time environmental response have had a profound impact on building design. In recent years, architects' focus has shifted from form to high-performance envelope. Smart building skins mimic the sensitivity of the human skin. As architect Doris Kim Sung remarked, "Building skins should be more similar to human skin" so that they are "much more dynamic and responsive."¹¹³ High-performance building skins use responsive surfaces with photovoltaics that react to sunlight, sensors that react to carbon dioxide levels, and phase-changing materials that respond to temperature changes.¹¹⁴

Semper is often credited with creating the metaphor linking skin and wall, leaving Pettenkofer a marginal figure in architectural history. Although Semper's *Bekleidung* principle stressed the tectonic aspects of architecture, it was Pettenkofer's skin analogy that highlighted the environmental performance of the building. From nineteenth-century "breathing walls" to today's high-performance envelopes, understanding of the building as a regulating membrane is a testament to the unsung legacy of Pettenkofer and the science of hygiene.

Notes

I would like thank Patricia Morton and anonymous reviewer for their insightful comments on early drafts of the text. The research presented in this article was supported by grants from Wellcome Trust in Medical History and Humanities and DAAD (German Academic Exchange).

¹ Cited in Anthony Vidler, "The b-b-b-Body: Block, Blob, Blur," in *The Body in Architecture*, ed. Deborah Hauptmann (Rotterdam: 010 Publishers, 2006), 134.

² Pettenkofer's contemporaries described him as "the father of experimental hygiene." F. Erismann, *Max von Pettenkofer: Ein Lebensbild* (Leipzig: Georg Thieme, 1901), 12.

³ See Caroline van Eck, *Organicism in Nineteenth-Century Architecture: An Inquiry into its Theoretical and Philosophical Background*, (Amsterdam: Architectura & Natura Press, 1994), 214-55.

⁴ On Pettenkofer's life, see Erismann, *Max von Pettenkofer*; Alfred Beyer, *Max von Pettenkofer* (Verlag Volk und Gesundheit, 1956); H. Breyer, *Max von Pettenkofer: Arzt im Vorfeld der Krankheit* (S. Hirzel, 1981); Karl Wieninger, *Max von Pettenkofer: Das Leben eines Wohltäters* (München: Hugendubel, 1987); Martin Weyer-von Schoultz, *Max von Pettenkofer (1818-1901): die Entstehung der modernen Hygiene aus den empirischen Studien menschlicher Lebensgrundlagen* (Frankfurt a.M.: Lang, 2006).

⁵ C. Francken, "Vorwort" in *Weyl's Handbuch der Hygiene: Bau und Wohnungshygiene*, (Leipzig: Verlag von Johann Ambrosius Barth, 1914), iii. Unless otherwise noted, all translations are my own.

⁶ Annmarie Adams has examined the similar role Victorian physicians played in the domestic sanitation movement. Annmarie Adams, *Architecture in the Family Way: Doctors, Houses and Women, 1870-1900* (Montreal: McGill-Queen's University Press, 1996), 36-72.

⁷ On the relationship between hygiene and physiology, see Didem Ekici, "The Physiology of the House: Modern Architecture and the Science of Hygiene," in *Healing Spaces, Modern Architecture, and the Body*, ed. Sarah Schrank and Didem Ekici (New York: Routledge, 2017).

⁸ Barbara Stafford, *Body Criticism: Imaging the Unseen in Enlightenment Art and Medicine*, (Cambridge, MA; London: MIT Press, 1991), 12. See also Bruce Haley, *The Healthy Body and Victorian Culture* (Cambridge, MA; London: Harvard University Press, 1978), 69.

- ⁹ Max von Pettenkofer, "Über die Mittel zur Förderung der Theorie und Praxis der öffentlichen Gesundheitspflege," *Zeitschrift für Biologie* 7 (1871): 503.
- ¹⁰ Hans Buchner, *Acht Vorträge aus der Gesundheitslehre* (Leipzig: B. G. Teubner, 1903), 3.
- ¹¹ Mikhail Mikhāilovich Bakhtin, *Rabelais and His World*, trans. Helene Iswolsky (Bloomington: Indiana University Press, 1984), 317-21.
- ¹² Mechthild Fend, "Bodily and Pictorial Surfaces: Skin in French Art and Medicine, 1790-1860," *Art History* 28, no. 3 (2005), 313.
- ¹³ Claudia Benthien, *Skin: On The Cultural Border Between Self And World*, trans. Thomas Dunlap (New York: Columbia University Press, 2004), 37-62, 95-110.
- ¹⁴ On the functions of the skin in physiology, see Hans von Ziemssen, "Physiologie," in *Handbuch der Hautkrankheiten*, ed. Hans von Ziemssen (Leipzig: F. C. W. Vogel 1883), 115-120.
- ¹⁵ Max von Pettenkofer, "The Value of Health to a City," *Bulletin of the History of Medicine* 10 (1941), 607.
- ¹⁶ See, for example, Carl Flügge "Kleidung und Hautpflege" (Clothing and Skin Care) in *Grundriss der Hygiene* (Leipzig: Veit & Co, 1897), 329-340; August Gärtner "Die Wärmeregulation des Menschen, die Kleidung und Hautpflege" (Heat Regulation of Humans, Clothing and Skin Care) in *Leitfaden der Hygiene* (Berlin: S. Karger, 1905), 174-94.
- ¹⁷ Max von Pettenkofer, "Ueber den Unterschied zwischen Luftheizung und Ofenheizung in ihrer Einwirkung auf die Zusammensetzung der Luft der beheizten Räume," *Dingler's polytechnisches Journal* 120 no. 91 (1851): 422.
- ¹⁸ *Ibid.*, 420.
- ¹⁹ Max von Pettenkofer, "Die atmosphärische Luft in Wohngebäuden," in *Wissenschaftliche Vorträge* (Braunschweig: Friedrich Vieweg und Sohn, 1858), 552.

²⁰Pettenkofer, “Über die Funktion der Kleider,” *Zeitschrift für Biologie* 1(1865): 180.

²¹ Buchner, *Acht Vorträge aus der Gesundheitslehre*, 52.

²² Max von Pettenkofer, *Beziehungen der Luft zu Kleidung, Wohnung und Boden* (Braunschweig: Friedrich Vieweg und Sohn, 1873), 35.

²³ Pettenkofer, “Über die Funktion der Kleider,” 194.

²⁴ Alina Payne, *From Ornament to Object: Genealogies of Architectural Modernism* (New Haven, London: Yale University Press, 2012), 30.

²⁵ Pettenkofer, “Über die Funktion der Kleider,” 194.

²⁶ Materialist explanations for architecture included that of German architect Heinrich Hübsch, who argued in the 1820s that architectural style should be derived from material, structural, social, and climatic conditions. Harry Francis Mallgrave, *Modern Architectural Theory: A Historical Survey, 1673–1968*, (Cambridge, UK: Cambridge University Press, 2005), 106-8

²⁷ “Die Erkenntniss der Functionen bedingt die äusseren Formen...” Pettenkofer, *Beziehungen der Luft zu Kleidung, Wohnung und Boden*, 35.

²⁸ Peter Collins, *Changing Ideals in Modern Architecture, 1750-1950* (Montreal: McGill-Queen’s University Press, 1998), 151.

²⁹ Semper’s four original types in architecture—the hearth, the roof, the enclosure, and the embankment— resembled Cuvier’s typology based on a limited set of basic forms. In an 1853 lecture he gave in London, Semper referred to Cuvier’s scientific work and observed an analogy between the variety of nature and “the creations of our hands” or “the works of industrial art.” He continued, “Like the works of nature, they are connected to each other by a few fundamental thoughts, which have found their simplest expression in some original

forms or types.” Quoted in Van Eck, *Organicism in Nineteenth-Century Architecture*, 214-34.

³⁰ The Albert Society was a women’s organization devoted to training female nurses.

Pettenkofer’s three lectures were collectively titled “The clothes we wear, the house we live in, and the soil we dwell upon.” One year later, the lectures were published as *Beziehungen der Luft zu Kleidung, Wohnung und Boden*.

³¹ This quotation comes from a chapter of Pettenkofer’s book that was translated into English and published as Max von Pettenkofer, “Relation of the air to the House we live in,” *Popular Science* 11 (June 1877): 196.

³² Ibid., 205.

³³ See, for example, Moritz Alsberg, *Die gesunde Wohnung* (Berlin: C. Habel, 1882), 15.

³⁴ Paula Baker-Laporte, Erica Elliott, and John Banta, *Prescriptions for a Healthy House: A Practical Guide for Architects* (New Society Publishers, 2008), 80.

³⁵ M. Versmann and H. Fürst, “Hygiene des Wohnhauses,” in *Handbuch der praktischen Hygiene*, ed. Rudolf Valentin Ludwig Abel (Jena: Fischer, 1913), 126.

³⁶ “Die Wohnung ist gewissermaßen unser weitestes Kleid...” Alsberg, *Die gesunde Wohnung*, 15-16.

³⁷ Alsberg, *Die gesunde Wohnung*, 22.

³⁸ August Gärtner, *Leitfaden der Hygiene* (Berlin: S. Karger, 1905), 195.

³⁹ Anna Fischer-Dückelmann, *Die Frau als Hausärztin: Ein ärztliches Nachschlagebuch der Gesundheitspflege und Heilkunde in der Familie mit besonderer Berücksichtigung der Frauen- und Kinderkrankheiten, Geburtshilfe und Körperpflege* (Stuttgart: Süddeutsches Verlags-Institut, 1905), 163.

⁴⁰ Lothar Abel, *Das gesunde, behagliche und billige wohnen* (Wien, Pest, Leipzig: A Hartlebens Verlag, 1894), 151-2.

⁴¹ Rudolf Emmerich, "Die Wohnung," in *Handbuch der Hygiene und der Gewerbekrankheiten*, ed. Max von Pettenkofer and H. v. Ziemssen (Leipzig: F. C. W. Vogel, 1894), 129.

⁴² Tessenow received a patent for his wall design. *Baugewerkszeitung*, "Die Tessenow-Wand," *Zeitschrift für das Baugewerbe* 57, no. 2 (1913). On the Tessenow Wall, see Ekici, "From Rikli's Light-and-air Hut to Tessenow's Patenthaus: *Körperkultur* and the Modern Dwelling in Germany," *Journal of Architecture* 13, no.4 (2008): 395-99.

⁴³ Tessenow was inspired by vernacular houses in northern Germany, the region where he grew up. To minimize the adverse effects of wind and rain, these houses had double brick walls with space in between. The gap helped the outer layer keep dry and prevented the inner layer from becoming wet. Ekici, "From Rikli's Light-and-air Hut to Tessenow's Patenthaus," 405.

⁴⁴ *Baugewerkszeitung*, "Die Tessenow-Wand," 12.

⁴⁵ *Zerlegbare, Transportable, Hygienische Haeuser im Dienste der Gesundheitspflege und Volkswohlfahrt mit besonderer Beruecksichtigung des System Döcker-Christoph & Unmack*, (Christoph & Unmack Company, 1903), 8.

⁴⁶ "Zerlegbare transportable Döckerbauten auf der Hygiene-Ausstellung in Dresden," *Die Hygiene*, no. 4 (1911), 105-6.

⁴⁷ Dr. tech. K. Brabbee, "Bericht ueber die wissenschaftliche Abteilung der Gruppe 'Ventilation und Heizung' der internationalen Hygiene-Ausstellung Dresden 1911," *Die Hygiene*, no. 5 (1911): 123.

⁴⁸ Dr. tech. K. Brabbee and Albert Brandt, *Sonder-Katalog fuer die Gruppe Ventilation und Heizung der wissenschaftlichen Abteilung der Internationalen Hygiene-Ausstellung Dresden 1911* (Dresden: Verlag der Internationalen Hygiene-Ausstellung 1911), 10.

⁴⁹ Le Corbusier, *The Radiant City*, (London: Faber and Faber Limited, 1964), 42.

⁵⁰ Ibid., 40.

⁵¹ These disciplines studied the material cultures and languages of peoples of the past, traditional communities, and indigenous peoples. Their interest in the cultures of people around the world, particularly in so-called primitive populations, stemmed from questions about German origins. In their search for primordial patterns, they analyzed the primitive body and the everyday artefacts that came in close contact with it. On the interaction among these disciplines, see Payne, *From Ornament to Object*, 96-111. On the relationship between anthropology and philology, see James Whitman, "From Philology to Anthropology in Mid-Nineteenth Century Germany," in *Functionalism Historicized: Essays on British Social Anthropology*, ed. George W. Stocking, Jr. (Madison, Wisconsin: The University of Wisconsin Press, 1984).

⁵² After completing his humanistic education at the prestigious Wilhelms Gymnasium, Pettenkofer initially aimed to study linguistics, but his uncle persuaded him to opt for studying pharmacy. Years later, as the university rector, he dedicated his annual welcoming address in 1869 to the role of humanistic academic high schools in preparing students for a university education, praising particularly such schools' focus on linguistic studies. See Max von Pettenkofer, *Wodurch die humanistischen Gymnasien fuer die Universitaet vorbereiten*, (München: J. G. Weiss, 1869).

⁵³ *Correspondenz-Blatt der deutschen Gesellschaft für Anthropologie, Ethnologie und Urgeschichte*, ed. C. Semper and A. v. Frantzius (Braunschweig: Friedrich Vieweg und Sohn,

1874), 23. In Germany, the term *Anthropologie* has been used to refer to what in Anglo-Saxon countries came to be called physical anthropology, whereas *Ethnologie* was equivalent to what is called today cultural anthropology. The two disciplines had interacted and their institutions were mixed in character acting as shared platforms for physiological, ethnological, linguistic, and historical analysis. Benoit Massin, “From Virchow to Fischer: Physical Anthropology and ‘Modern Race Theories’ in Wilhelmine Germany,” in *Volksgeist as Method and Ethic: Essays on Boasian Ethnography and the Germany Anthropological Tradition*, ed. George W. Stocking, Jr. (Wisconsin: The University of Wisconsin Press, 1996), 82

⁵⁴ Munich was at the forefront of anthropological research. From 1886 to 1906, Ranke chaired the only anthropological institute in Germany at the University of Munich, where Pettenkofer taught. Massin, “From Virchow to Fischer, 82-85.

⁵⁵ Pettenkofer, “Die atmosphärische Luft in Wohngebäuden,” 552.

⁵⁶ Although a direct link between the two men has not been established, their work was occasionally featured in the same publications. For example, *Beilage zur Allgemeinen Zeitung Muenchen* no. 362, (28 December 1865) features an article on cholera by Pettenkofer and a review of Klemm’s book *Vor 50 Jahren: Culturgeschichtliche Briefe* (1865).

⁵⁷ Gustav Klemm, *Allgemeine Cultur-Geschichte der Menschheit*, vol. 1-10 (Leipzig: B. G. Teubner, 1843-52).

⁵⁸ On Klemm, see Chris Manias, “The Growth of Race and Culture in Nineteenth-Century Germany: Gustav Klemm and the Universal History of Humanity,” *Modern Intellectual History* 9, no. 1 (2012).

⁵⁹ George S. Williamson, “Kulturgeschichte,” in *A Global Encyclopedia of Historical Writing*, ed. D. R. Woolf (Routledge 1998), 519.

⁶⁰ Gustav Klemm, *Allgemeine Cultur-Geschichte der Menschheit*, vol. 1 (Leipzig: B. G. Teubner, 1843), 24. On Klemm's concept of culture, see Johan Goudsblom, *Nihilism and Culture* (Oxford: Basil Blackwell, 1980), 53-56.

⁶¹ Klemm, *Allgemeine Cultur-Geschichte*, 1, 182.

⁶² Klemm, *Die menschliche Kleidung. Culturgeschichtliche Skizze* (Joh. Friedr. Jencke, 1854), 4.

⁶³ "Die Wohnung ist ja überall eigentlich nur eine erweiterte, ausgedehnte Kleidung oder eine Verstärkung und Fortsetzung derselben." Klemm, *Allgemeine Cultur-Geschichte der Menschheit*, 2:226. In fifty years, around 1900, this view of the dwelling as an expansive dress would be widely common in the *Kunstgewerbe* movement.

⁶⁴ Klemm, *Die menschliche Kleidung*, 15.

⁶⁵ For example, in 1835 theologian Johann Georg Riegler observed, "Unlike animals which are covered with feathers and fur, the human body is not protected against the atmospheric conditions and in every climate they need cover [*Bedeckung*] and dressing [*Bekleidung*] and also dwelling [*Wohnung*]." Johann Georg Riegler, *Christliche Moral nach der Grundlage der Ethik des M. v. Schenkl*, vol. 2 (Augsburg: Verlag der Kranzfelderschen Buchhandlung, 1835), 419. Jakob Brand claimed that man had a similar relationship to *Bekleidung* and shelter (*Obdach*), as both protected him from the elements. Jakob Brand, *Anfangsgrunde der Naturwissenschaft für die Jugend* (Frankfurt: Andreaeischen Buchhandlung, 1832), 96.

⁶⁶ Klemm, *Allgemeine Cultur-Geschichte*, 2:35.

⁶⁷ Pettenkofer, "Über die Funktion der Kleider," 193

⁶⁸ Ibid.

⁶⁹ Klemm, *Allgemeine Cultur-Geschichte*, vol. 1, 215.

⁷⁰ Ibid., 254.

⁷¹ Ibid., 185.

⁷² Georges Vigarello, *Concepts of Cleanliness: Changing Attitudes in France Since the Middle Ages* (Cambridge: Cambridge University Press, 2008), 167-76.

⁷³ Adolf Loos, "Ornament and Crime," in *Programs and Manifestoes on 20th-century Architecture*, ed. Ulrich Conrads (Cambridge, MA: The MIT Press, 1971).

⁷⁴ Ibid., 19.

⁷⁵ Ibid., 20.

⁷⁶ On Loos's work within the context of contemporaneous scientific theories of evolution and ornament by Charles Darwin, Ernst Haeckel, and Cesare Lombroso, see Jimena Canales and Andrew Herscher, "Criminal Skins: Tattoos and Modern Architecture in the work of Adolf Loos," *Architectural History* 48, (2005): 235-56.

⁷⁷ Loos, "Ladies' Fashion (August 21, 1898)," in *Spoken into the Void: Collected Essays 1897-1900*, translated by Jane O. Newman and John H. Smith (Cambridge, MA: MIT Press, 1982), 99; Loos, "Men's Fashion (May 22, 1898)" in *Spoken into the Void*, 11.

⁷⁸ Adolf Loos, "Plumbers," in *Plumbing*, ed. D. S. Friedman and Nadir Lahiji (New York: Princeton Architectural Press, 1997), 18.

⁷⁹ Wilhelm Wackernagel, "Haus Kleid Leib," *Zeitschrift für deutsches Alterthum* 6 (1848): 298.

⁸⁰ Ludwig Tobler, "Haus, Kleid, Leib," *Germania: Vierteljahrsschrift für Deutsche Alterthumskunde* 4 (1859): 160.

⁸¹ Ibid., 173

⁸² "Die Haut is näher als das Hemde..." Ibid., 166.

⁸³ Ibid.

⁸⁴ Ernst Kapp, *Grundlinien einer Philosophie der Technik: zur Entstehungsgeschichte der Cultur aus neuen Gesichtspunkten*. (Braunschweig: George Westermann, 1877), V-VI. On Kapp's philosophy, see Payne, *From Ornament to Object*, 79-82.

⁸⁵ Kapp, *Grundlinien einer Philosophie der Technik*, 80-125.

⁸⁶ Ibid., 266-67

⁸⁷ Ibid.

⁸⁸ Ibid., 267-69.

⁸⁹ Ibid., 268; Theodor Wittstein, *Der Goldene Schnitt und die Anwendung desselben in der Kunst* (Hannover: Hahn'sche Hofbuchhandlung, 1874).

⁹⁰ Kapp included lengthy quotes from Adolf Zeising's *Neue Lehre von den Proportionen des menschlichen Körpers* [New Theory of the Proportions of the Human Body] (Leipzig: Rudolph Weigel, 1854). Kapp, *Grundlinien einer Philosophie der Technik*, 209-56.

⁹¹ Zeising, *Neue Lehre von den Proportionen des menschlichen Körpers*, v, 393-97. On Zeising, see Marcus Frings, "The Golden Section in Architectural Theory", *Nexus Network Journal* 4, no. 1 (Winter 2002): 18-20.

⁹² Kapp, *Grundlinien einer Philosophie der Technik*, 270. See also August von Eye, "Das Kunstgewerbe der Neuzeit," *Der Salon für Literatur, Kunst und Gesellschaft*, no. 4 (1876): 590.

⁹³ Harry Francis Mallgrave, "Gustav Klemm and Gottfried Semper," *RES: Journal of Anthropology and Aesthetics* 9, (Spring 1985), 68-79.

⁹⁴ Sonja Hildebrand contests the view that Semper may have had contact with Klemm while in Dresden. Sonja Hildebrand, " 'Nach einem Systeme zu ordnen, welches die inneren Verbindsfäden dieser bunten Welt am bestenzusammenhält': Kulturgeschichtliche Modelle bei Gottfried Semper und Gustav Klemm," in *Gottfried Semper, Dresden und Europa: Die*

moderne Renaissance der Künste, ed. Henrik Karge (München: Deutscher Kunstverlag, 2007), 239.

⁹⁵ Gottfried Semper, *Der Stil in den technischen und tektonischen Künsten; oder, praktische Aesthetik. Ein Handbuch für Techniker, Künstler und Kunstfreunde*, vol. 1 (Frankfurt a. M.: Verlag für Kunst und Wissenschaft, 1860), 1, 6.

⁹⁶ Gottfried Semper, *Die vier Elemente der Baukunst: Ein Beitrag zur vergleichenden Baukunde* (Braunschweig: Friedrich Vieweg und Sohn, 1851). On Semper's *Bekleidung* principle, see Harry Francis Mallgrave, *Gottfried Semper: Architect of the Nineteenth Century* (New Haven, CT: Yale University Press, 1996), 85-88, 180-81, 293-302.

⁹⁷ Semper, *Die vier Elemente der Baukunst*, 56.

⁹⁸ *Ibid.*, 57.

⁹⁹ Gottfried Semper, *Style in the Technical and Tectonic arts, or, Practical aesthetics*, trans. Harry Francis Mallgrave (Los Angeles: Getty Research Institute, 2004), 247.

¹⁰⁰ *Ibid.*, 248.

¹⁰¹ *Ibid.*

¹⁰² The concept of a drive towards ornament that first manifested itself on the body surface and then in crafts had appeared in Klemm's work and subsequently emerged in works on ornament such as Owen Jones' *The Grammar of Ornament* (1856). Alina Payne, "Wölfflin, Architecture and the Problem of *Stilwandlung*," *Journal of Art Historiography* 7 (2012): 12.

¹⁰³ Semper, *Style* 171.

¹⁰⁴ *Ibid.*, 172.

¹⁰⁵ Gottfried Semper, "Über die formelle Gesetzmässigkeit des Schmuckes und dessen Bedeutung als Kunstsymbol," in *Kleine Schriften*, ed. Manfred Semper and Hans Semper (Berlin & Stuttgart: W. Spemann, 1884), 308.

¹⁰⁶ *Style* 172.

¹⁰⁷ Gottfried Semper, *Der Stil in den technischen und tektonischen Künsten; oder, praktische Aesthetik. Ein Handbuch für Techniker, Künstler und Kunstfreunde*, vol. 2 (München: Friedrich Bruckmann's Verlag, 1863), 208. King Ludwig I commissioned Pettenkofer to rediscover the production process of the mysterious haematinum of ancient times. He provided the experimental proof that it was in fact a copper-colored glass.

¹⁰⁸ Pettenkofer, "Die atmosphärische Luft in Wohngebäuden," 552.

¹⁰⁹ In his 1869 text "On Architectural Styles," and his 1870 manuscript of the third volume of *Der Stil*, Semper distanced himself from Cuvier's functional morphology and materialist explanations in architectural history by discrediting evolution in biology based on functional, technical or material aspects as the sole factor in understanding architectural styles. Instead, he regarded human creativity to be the most important factor. Mallgrave, "A Commentary on Semper's November Lecture" *RES: Journal of Anthropology and Aesthetics* 6, (Spring 1983): 31.

¹¹⁰ For example, art historian Jakob von Falke analyzed dress and dwelling as the expression of the *Zeitgeist*: "Should we not consider that it is worthwhile to decorate [our apartment] so that it is entirely in harmony with our own feelings and needs, as it were an expansive dress with its aesthetic character fitting so closely to our own ways of living just like the dress fitting our body?" Jacob von Falke, *Die Kunst im Hause* (Wien: Carl Gerold's Sohn, 1871), 2.

¹¹¹ Payne, *From Ornament to Object*, 72-82.

¹¹² For example, Hubert Palm has argued, "Clothing is the second outer skin. The house is the third outer skin. The interior comes before the exterior. A healthy house can be utilized to the

degree that you are eating, drinking healthily and wearing healthy clothes.” Hubert Palm, *Das gesunde Haus: Unser naher Umweltschutz*, 10 ed. (Reichl, 1992), 66.

¹¹³ Anderson Lamar, “Biologist-Turned Architect Invents ‘Breathing’ Metal Building Skin,” *Architizer*, (October 2012), <http://architizer.com/blog/doris-kim-sung-thermo-bimetal/> (accessed 16 Nov. 2013).

¹¹⁴ On high-performance building skins see Kathy Velikov and Geoffrey Thuen, “Responsive Building Envelopes,” in *Design and Construction of High-Performance Homes*, ed. Franca Trubiano (New York: Routledge, 2013).