Konrad Lorenz with colleagues at the Max Planck Institute for Behavioral Physiology, Seewiesen, Germany, ca. 1970. Konrad Lorenz Archive, Vienna.

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Watery Milieus: Marine Biology, Aquariums, and the Limits of Ecological Knowledge circa 1900

CHRISTINA WESSELY
TRANSLATED BY NATHAN STOBAUGH

Thinking with the Aquarium

In 1980, when Konrad Lorenz was asked on the occasion of an award ceremony to look back on his career and reflect on what had most influenced his research, he singled out neither a particular theoretical perspective nor a methodological approach, but instead spoke about the material culture of his studies. It was the aquarium that had made the pursuit of environmental science seem necessary, as if the problem had been "right in front of his nose."[1] For an aquarium was, according to Lorenz, not simply a neutral container that held one or more animals but rather a vessel that inspired one to direct attention at the "whole." "The great educational importance of the aquarium for any biologist lies in the fact," the behavioral scientist underscored in his speech, "that you have before yourself an ecosystem that either prospers as a whole, or the fish that you want to study scientifically will be lost." The glass tank compelled biologists toward "ecosystem research [*Ökosystemforschung*]."[2]

The fact that Lorenz understood the aquarium as a material inspiration for the emergence of the study of surroundings (*Umgebungswissen*) toward the end of the twentieth century is not mere biographical happenstance. Rather, this idea must be understood within a tradition with deep historical roots—a tradition that assigns crucial importance to the aquarium as a reference point for biological thought and ecological theory.

In his *Leitfaden in das Studium der experimentellen Biologie der Wassertiere* (Guide to the study of the experimental biology of aquatic animals), published seventy-five years before Lorenz's speech, Jakob von Uexküll emphasizes the importance of the "continuous and thorough observation of the living animal in its milieu,"[3] a fundamental requirement (even if one is working, like Uexküll, at the Zoological Station directly on the Gulf of Naples) that becomes possible to fulfill only when both marine animals and

their surroundings can be relocated: in short, by working with aquariums. "That part of the outside world that affects the animal through the receptors is called its milieu," wrote Uexküll in 1905. Expanding on the idea of the "milieu," he would outline the difference between "environment" (*Umwelt*) and "surroundings" (*Umgebung*). While *Umgebung* for Uexküll designated an organism's somewhat "objective" surroundings (which it shares with other living beings), he defined the *Umwelt* of an organism as the perceptual world in which the organism exists and functions as a subject. At the beginning of the twentieth century, however, his ecological considerations still revolved around the concept of *milieu* (more akin to his later understanding of "environment" than of "surroundings"): "The difficulty of determining the perceivable stimuli for each animal lies for us in the fact that we only know that part of the outside world that is our own milieu."[4] So how does one create a milieu for organisms whose environment is not that of the researcher, but rather offers the "normal conditions" of the organisms' lives?[5] By raising such questions, the aquarium became epistemologically volatile for Uexküll. Consequentially, it was only logical for him to begin the third part of his book *Bausteine zu einer biologischen Weltanschauung* (Building blocks for a biological worldview), which presents nothing less than "The New World Picture," with a chapter on "The Tropical Aquarium."[6] Uexküll developed his environmental teaching decidedly on the basis of his studies in marine biology and envisioned the environment of every living being—not just metaphorically, but on the basis of concrete research experiences—as a "solid but invisible glass house."[7]

The aquarium is useful to *think with*. The necessary reduction of complexity, which the scientist accomplishes with the transfer of the sea into a glass cuboid, results in an increased understanding of complex relationships; the specific materiality of the research apparatus opens up new, hitherto unformulated research questions that go far beyond the originally central epistemic objects. For researchers such as Lorenz or Uexküll, the aquarium did not appear to be a necessary evil, nor an unfortunately artificial milieu, but rather a "clear vessel [for their] imagination," which, in particular, guided the production of ideas and theories about the "environment."[8]

The thesis pursued in this article is, first, that "water biology" (*Wasserbiologie*), a term that appeared around 1900 to encompass both marine biology and limnology, must be considered a central site for the development of modern ecology; and, second, that the emergence of knowledge concerning relationships between the organism and its environment and the attendant formation of ecological terms owe a striking debt to the material research equipment that made these intellectual developments

possible. One concept, which played a central role in these epistemological formations, was that of the "milieu" (*Milieu*), which is both related to and distinct from the material medium that surrounds animals. The aquarium provoked questions about the characteristics of specific milieus, their boundaries, and their interdependencies with the individual entities that they encompass. The aim of the present article is to demonstrate the ways in which complex demands presented by the collection, stabilization, and exhibition of "living environments" in and behind glass affected the definition of milieu and, in turn, the development of theoretical concepts in response to the observable proliferation of milieus.

Since the mid-nineteenth century, discourse about the milieu was ubiquitous not only in the life sciences. Georges Canguilhem proposed the term in *Le vivant et son milieu* as a way of denoting "the universal and necessary medium for the experiences and existence of living beings" and, therefore, as a "fundamental category of contemporary thought."[9] Nevertheless, with very few exceptions, the definition of this concept remained strangely vague. Likewise, few studies deal directly with the concrete constellations of attempts to differentiate more precisely between different concepts of the milieu, for example, with terms such as environment (*Umwelt*) and surroundings (*Umgebung*), ambience (*Ambiente*), modes of living (*Lebensweise*), habitat (*Lebensraum*), or ecosystem (*Ökosystem*).

The history of the milieu concept is substantial. Closely related to *ambiens*—the notion that human beings exist in agreeable relationship to the universe through a certain means of enfoldment—the Latin idea of the *medium* came to consciousness through the natural sciences and theories of ether. Over the course of the eighteenth century, this became the French concept of the *milieu*, which served as a productive idea for various disciplines at the beginning of the nineteenth century. Within the life sciences, the employment of this concept by Jean-Baptiste Lamarck is particularly important. He usually uses the term "circumstances" (*circonstances*) to describe the adaptation of an organism to its environment, but occasionally also "milieu." Hippolyte Taine introduced the idea to sociological theory, not in the sense of a physical medium, but rather as an indication of numerous factors that could be considered together as the cause of human lifestyles.[10] Auguste Comte contributed substantially not only to the sociological but also to the biological contours of the milieu concept as the sense of an enclosing space (*Raum*), which designated the whole ensemble of external circumstances necessary for the existence of an organism. Influenced by Comte, the idea of the milieu experienced a boom among the life sciences of the mid-nineteenth century, from plant and animal geography to physiology and bacteriology.

With "water biology," a new disciplinary site presented itself at the turn of the twentieth century, one in which a special emphasis was placed on the concept of the milieu and in which the processes of its transformation, extension, and reinterpretation could be concretized.

In her book *Modern Nature*, Lynn Nyhart shows that interest in the relationships linking a (living) organism to its surroundings and to other organisms as well as, relatedly, attention to the specific qualities of environments and milieus intensified within German natural sciences during the second half of the nineteenth century. Nyhart describes this shift of interests from taxonomic systematizations to the study of the situatedness of the living organism and its adaptations to the world as the rise of the "biological perspective."[11] It is not surprising that such a research agenda also implied a highly ecological perspective. However, what has not been analyzed at length is the fact that most of the protagonists of this paradigm shift—especially those who, starting in the 1870s, began to develop a theoretical terminology to describe the relationship between organism and environment—worked with aquariums.

For example, the zoologist Karl Möbius, "who transformed the broad, undertheorized ecological, environmentalist, and functionalist ideas of the practical naturalists into scientific theory,"[12] and who was involved in the establishment of Germany's first saltwater aquarium in Hamburg (1864), wrote a guide for the aquarium's visitors and regularly published articles on marine biology and aquarium studies in popular papers to promote natural science. Through his engagement with water biology, he developed his concept of "biocenosis" (*Biozönose*) or "life community" (*Lebensgemeinschaft*), which describes the complex dependency structures binding organisms with each other and their environment. The aquarium presented itself to him (as it would to Uexküll and Lorenz later) as a material basis of ecological theorization. For Möbius, "aquarium work afforded—demanded, even—a focus on the relations of the organisms to their environments in a manner perhaps even more intense and direct than the zoo's land organisms called for."[13] It was no coincidence, then, that the main medium of Möbius's research, crucial for his understanding of biocenosis, was water.[14] In fact, before beginning any research proper, he had to contend with the animals' environments much more intensively than his colleagues dealing with land animals needed to; otherwise, the animals simply would not survive. As a water biologist he first had to know about the milieus; he had to "connect with nature" in order to "scientifically ascertain the principles of the aquarium" and "artificially establish the highest possible perfection."[15] He had to become an ecologist before he could be a biologist.

The aquarium played a similar role for Friedrich Junge, a Möbius student who is considered a protagonist of early ecology. As a teacher, Junge was committed to reforming the natural science curriculum in secondary schools and to advocating for an object-based pedagogy (*Anschauungspädagogik*) that aimed to teach students primarily about biological connections by means of simple examples from the environment already familiar to them. In his magnum opus *Naturgeschichte in der Volksschule: Der Dorfteich als Lebensgemeinschaft* (Natural history in elementary school: The village pond as life community), he designed a curriculum that opposed the teaching of taxonomic systematics and instead focused on the study of the relationships between organisms and the environment. Excursions into nature played a central role. Students were asked to take field trips to meadows, fields, and, above all, to rivers, lakes, and ponds. To this end, the book contains detailed instructions on how to carry out work with aquariums and terrariums, because it was there, according to Junge, that one could best study the complex system of organisms and their physico-chemical environment, as he knew from personal experience.

The list of scholars whose environmental thinking was similarly structured around the aquarium could be continued. Above all, animal geography first gained its ecological orientation through marine research. For example, Friedrich Dahl, a participant in the Plankton Expedition and author of the *Grundlagen einer ökologischen Tiergeographie* (Foundations for ecological animal geography), introduced the term *biotope* (*Biotop*) into scientific discourse in 1908. Already in 1893, the geologist and oceanographer Johannes Walther, on the basis of a two-year research period at the Zoological Station in Naples, where he had carried out sedimentological and biological research (and of course worked with aquariums), coined the term *living districts* (*Lebensbezirke*) to describe the specific constellations of physical environments that determine the propagation of different species.

The key role of the aquarium in the generation of ecological knowledge, adumbrated above, has yet to be described systematically. Its function at the interface of biological and ecological knowledge production will now be explored (with an emphasis on the history of saltwater aquariums, even though many of the same issues also apply to freshwater aquariums). This examination will be carried out less in the sense of a chronological history than as a series of systematic questions related to this area of knowledge production. These questions are inextricable from the problems that stand at the shared origins of ecology and marine biology. What kind of ecological knowledge had to be generated, or invoked, when working with

marine organisms? And under what circumstances exactly did marine biology and popular aquarium studies discover the milieu surrounding their objects of knowledge?

Media Thresholds

Around the middle of the nineteenth century, as knowledge about nature and life on earth was growing day by day and optimism for scientific progress appeared boundless, it began to seem all the more irritating that hardly anything was known about large portions of the globe. These areas included parts of Africa as well as the polar regions, but above all a place that remained far more obscure than all others: the ocean.[16]

While the sea's surface as well as its coasts and beaches were already well researched and had already become places of bourgeois leisure culture, a largely unknown world existed only a few hundred meters away. As late as 1850, there were no technological means of determining the depths of the ocean and the question of deep-sea animal life remained unanswered.

While many imagined that these unknown regions must be populated with fabulously enormous creatures whose size was assumed to match the immensity of the ocean, natural scientists were more likely to contend that no organism could survive at such great depths. The latter view was bolstered by the fact that nothing had been brought successfully to the surface from a depth of more than 300 fathoms (approximately 550 meters).[17]

In spite of intense efforts to study this potential habitat, the ocean remained until well into the nineteenth century a fantastical, often anxiety-producing place that the collective imagination populated with "mythical beings," "fairytale creatures," and other "strange forms" of the deep ocean.[18] The ability of natural science to eliminate these fantasies remained questionable. Whereas the zoologist Gustav Jäger believed it possible in 1868 that "the prophesies of yore will be fulfilled and gigantic animals will arise from the deep . . . while the more comprehensive our methods of exploring the sea's depths, the more creatures it will offer up," Walther worried that science would lead to disenchantment: "The telescope has made the sky lifeless, and won't the bathometer and the trawl net destroy the realm of the Oceanids and the harmonious beauty of the ocean?"[19]

In order for oceanographers to confirm the fabled narratives of undersea life or to distance the ocean from such fairy tales, they first had to get hold of their objects of knowledge. The wistful interjection of a natural scientist in 1862 suggests that this undertaking also presented itself as a problem of media: "If only we were granted the possibility of wandering about as freely on those undersea climbs as we do on solid land; or if our eyes could penetrate

the clear salt tides as easily as the space of the atmospheric ocean!"[20] The "manifold veil" that "surrounds the inner life of marine animals," according to Möbius, was the main reason that scientists were still "fumbling beginners" in the study of their life circumstances.[21]

At first glance, the fact that researchers and their objects are subject to different media conditions may seem unproblematic. This is, however, neither technologically nor epistemologically trivial. The process of overcoming this medial threshold—which quite concretely separates two media, namely water and air, but also divides different living spaces and environments, becoming in the process a "milieu threshold"—is not easy to accomplish. When brought on land, often little remains of fragile marine organisms, while even the best-equipped researcher is highly encumbered underwater. Even operating on the surface or the coasts turned out to be cumbersome around 1900, when many biologists had to "take an entire laboratory with them to the sea."[22] So it became necessary to institutionalize means of overcoming this milieu threshold, of relocating the ocean to places that allowed its study. "Here, the aquarium presents itself as a mediating agent; what remains outside, in nature, hidden from our observations, here . . . lives and grows before our eyes in a small, glass-walled container."[23] The transfer of the ocean into the aquarium—itself "a small ocean between walls of glass" but unlike the immense and impenetrable original and "accessible to the eye from all sides"—represented the most prominent and consequential of these means.[24]

Acclimatization

The scientific history of the aquarium begins in the first half of the nineteenth century.[25] However, work by naturalists such as Jeanne Villepreux-Power, Anna Thynne, Nathaniel Bagshaw Ward, and Robert Warington remained largely isolated undertakings.[26] The aquarium did not experience its first real boom in the sciences until a few decades later, coinciding with the paradigm shift from the study of taxonomic relations to morphological research on living animals, especially in the field of embryology.[27] While the discipline of physiology regularly dealt with living animals in experiments, this was hardly the case for zoological or anatomical research until well after 1850. "At that time," remembered Hans Przibram, later the director of Vienna's Biologische Versuchsanstalt (Institute of Experimental Biology), recalling his studies around 1900, "there were no institutions that dealt with living animals (excepting physiology) among the zoological institutes. At these institutes one carried out comparative investigations on dead objects and genealogical trees of the extant and the extinct."[28] Those who, like Przibram,

wanted to dedicate themselves to experimental biology on living organisms had to travel to the zoological stations that had been established on European coasts since the 1870s, such as those in Roscoff, France (1872); the Austro-Hungarian Imperial and Royal Zoological Station in Trieste (1875); the station founded by the English Marine Biological Association in Plymouth (1884); the Zoological Station of the Berlin Aquarium in Rovigno, then part of Austria-Hungary (1891); or the Royal Biological Institute on Heligoland, Germany (1892). Their locations guaranteed easy access to an abundance of marine life and secured the conditions necessary to create and stabilize "natural milieus," the necessary prerequisite for and foundation of experimental biology. The most prominent among these was the Zoological Station in Naples (1872), founded at the initiative of Ernst Haeckel's student Anton Dohrn, which became in the following years a "Mecca of biologists in every quarter of the globe."[29] Like many of his colleagues, Dohrn was convinced that the question of evolution would find "the source of its slow but continuously progressive answer primarily in the study of marine animals."[30] According to the biologist in 1872, the dearth of knowledge in some of the most central areas of life science research could be attributed "above all . . . to the mechanical difficulties of observation."[31] Marine organisms, the research of which promised to answer embryological questions in particular, "require a constant stream of salt water to keep them alive, a stream which is only to be had by the help of an aquarium. It is principally due to the absence of such aquariums that our knowledge of the development of fishes is still so rudimentary."[32] Especially in light of the experimental research results (always carried out with aquariums) achieved at the station, many came to share Dohrn's perception of marine biology as a leading discipline. "The most significant discoveries," proclaimed the *Blätter für Aquarien- und Terrarienkunde* (Papers for aquarium and terrarium studies) in 1903, "that form the theoretical basis of biology's modern framework have been made via the study of marine organisms."[33] Uexküll would also assert in 1913 that "the greatest strides in fertilization and gestation studies of the last twenty years" had been thanks "almost exclusively to sea creatures."[34]

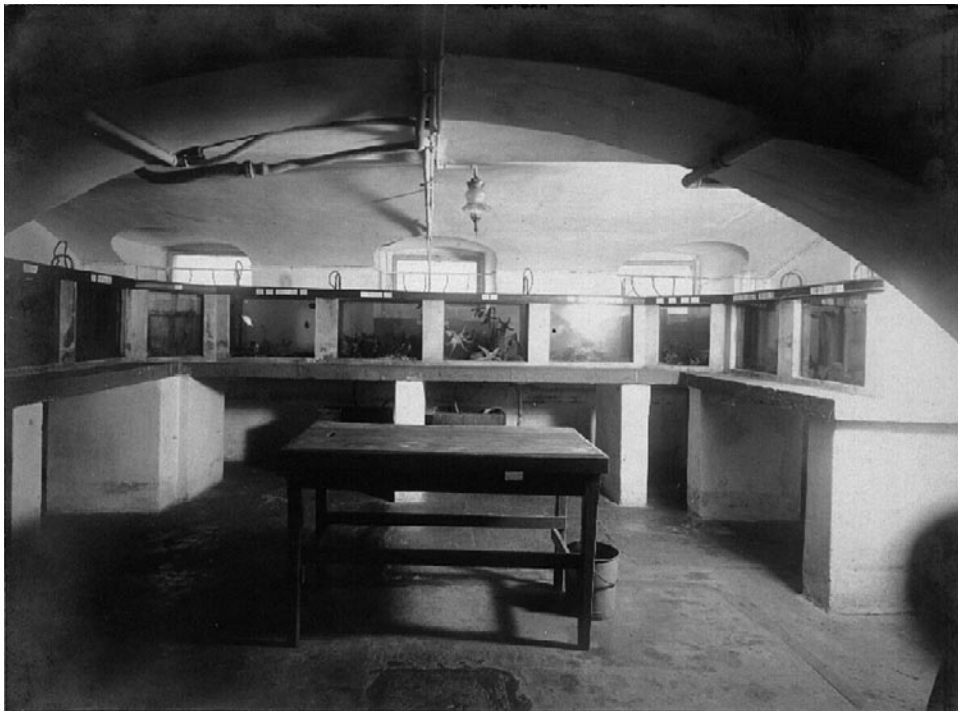
Anyone who imagined that in Trieste, Naples, or Rovigno one could simply fish the marine organisms out of the sea, put them into aquariums without further ado, and immediately start researching on dry land, was sorely mistaken. To obtain fish, mollusks, or crustaceans, most of the zoological stations worked closely with local commercial fishermen, who brought the scientists "every interesting animal."[35] In many places there were "specially trained fishery servants [*Fischereidiener*] employed by the institute."[36] However, the yield of fishing voyages could only be deposited into the tanks

of the research stations after first undergoing "treatment."[37] A detailed description by the preparator Hans Zimmermann, who was employed at the Zoological Station in Rovigno, shows how laborious the process of establishing a "bit of self-regulating nature" in an aquarium actually was.[38] Milieu, as Zimmermann's description makes clear, does not exist prior to the moment when a living being is placed inside it, but rather results from a delicate balance between animals, plants, and their material surroundings. This acclimatization process sometimes took several days, often involved a whole range of apparatuses and equipment, and required specific technical and experiential knowledge, all with the goal of making the complex process itself disappear. At its conclusion, the animal should be "at home," finding itself in an environment structurally indistinguishable from its natural one.

The process began with the sorting of the captured animals, distinguishing "not according to species, but only by the constitution of the organisms": "First, the frail and delicate animals are separated from the larger, tougher and most resilient, then the most sensitive and hard-to-acclimatize creatures are placed in the so-called fish boxes."[39] These fish boxes were small, flat, fully enclosed boats with narrow slits on the sides and a small hatch on the upper cover, attached to buoys or wharves in order to keep them beneath the water's surface. While more easily acclimatized animals could be transferred to the aquariums of the Zoological Station immediately after being caught, octopuses, crabs, tunicates, seahorses, pipefish, and various types of sponges became, in these fish boxes, "habituated to the small space while still exposed to running water and tidal currents."[40] After a few days, they were taken to the research institute, where some were immediately placed in large cement basins while others had to be further housed in an "acclimatization tub," a container permanently supplied with new water, where they gradually adjusted from total darkness to their new light conditions.

Only a portion of the species under study had to go through this process, though. The "life-tenacious [*Lebenszähe*]" were only cleared of mud and algae before they were placed in large cement storage tanks "and acclimated themselves there quite tolerably, without exhibiting any notable damage."[41] These tanks were anything but isolated containers, exhibiting—like all aquariums—fluid boundaries with the animals' natural surroundings. "All tanks," explains Zimmermann,

> have continuous outflow and inflow, day and night. Seawater is pumped mechanically from the ocean into the reservoir, which is housed on the third floor of a separate building constructed for this purpose. From there [the seawater] flows through lead pipes to the aquariums in the



laboratories and the tanks in the acclimatization and storage rooms. Drainage is directed back into the sea through channels lined with brick.[42]

In this context, acclimatization denoted the gradual replacement of the animals' former surroundings by their new ones with the aim of creating a milieu that resembled the natural one, even as it necessarily differed from it. Acclimatization was the precondition for experimental biology, and it also afforded the possibility of bringing marine animals, along with their surroundings, inland. Many of the zoological stations served as outposts of biological research institutions, providing them with "living and preserved material . . . for study and instructional purposes."[43] Moreover, they operated, according to the Austrian zoologist Carl Cori at the Imperial and Royal Zoological Station in Trieste, primarily as state research institutes and thus did not sell, but gladly gave, sea animals to private persons, "since perhaps in this way something can be contributed, since the presence of interesting sea creatures in inland aquariums might promote a fondness for contemplating and engaging with nature as one of the noblest means of education."[44] And so, fish were placed in balloons made of sheet iron or glass jars, while algae, anemones, crabs, mussels, and snails were acclimatized and thus made "ripe for shipping" between wet sponges "sent as five-kilogram postal packages via express delivery or courier service."[45] Since tin balloons or sponges, often transported in the dark interior of packages across half of Europe, were hardly the proper surroundings for marine organisms, numerous accounts document animals that reached their destination dead or injured. But those fabulous creatures that, despite the hostile milieus, arrived safely to aquarium lovers in the European metropolises might have seemed like dispatches direct from the bottom of the sea, bearing no trace of the days and weeks of acclimatization procedures preceding their relocation.

The aquarium room at the Austro-Hungarian Imperial and Royal Zoological Station, Trieste, ca. 1890 (?). Deutsches Technikmuseum Berlin, photo collection "Museum für Meereskunde," R 11007.

Knowledge of the Home—Aquarists as Ecological Practitioners

The railroad had delivered the wondrous ocean creatures to the European capitals; now they just had to be properly framed by their environments. Should one buy a box aquarium with a pressurized bubbler encased in rock, or should one invest in the "Rounded Hexagonal Dragon Aquarium with Gallery"?[46] Since at least the 1880s, nature-loving Germans faced such pressing decisions.

The "aquarium craze" had taken hold in the English bourgeois living room three decades earlier. Intense interest in the ocean (and its outposts) had spread there, mostly thanks to naturalist Philipp Henry Gosse. Gosse's research materials were supplied by W. Alfred Lloyd, who had established an aquarium warehouse near the London Aquarium (1853) in Regent's Park, which provided the sea-crazed English with everything an aquarist's heart could desire. With some delay, but consequently all the more long-lasting and professionally organized (since biological oceanography could be integrated into the existing infrastructure of popular natural studies), aquarium enthusiasm finally reached Germany. A variety of merchants selling natural materials began to offer aquatic animals and plants as well as all kinds of aquarium supplies. In clubs and societies, aquarists could exchange experiences with their hobby in a number of natural history journals, particularly the specialized publication *Blätter für Aquarien- und Terrarien-Freunde* (Papers for friends of aquariums and terrariums).[47]

The transfer of the sea into the salon was, according to contemporary descriptions, largely smooth and uncomplicated: the aquarium was considered nothing less than a section of the ocean, the animals no different than they were in the wild. A trope that circulated in countless variations throughout contemporary oceanographic texts over these decades referred to a "watery medium" that completely enveloped the organism, a motif that denoted a seemingly stable ambience reduced to its materiality.[48] Such a definition of milieu refers to the physical tradition of this concept, which understood a body's environment to be essentially its material surroundings (i.e., its *medium*).[49] The element—in this case water—stands in for the authenticity of that which it surrounds, and the aquarium thus appears to be a glass phantasm of a media change without an actual change of media. With the invention of the aquarium, the milieu threshold between water and land, between field and laboratory, seemed possible to overcome. The "sectioning" of a tiny part of the ocean left almost no traces behind; not only were individual organisms captured, brought to the surface, and placed in the aquariums of research centers or bourgeois salons, but with them, it was said, their entire milieu. Consequently—according to an equally widespread and epis-

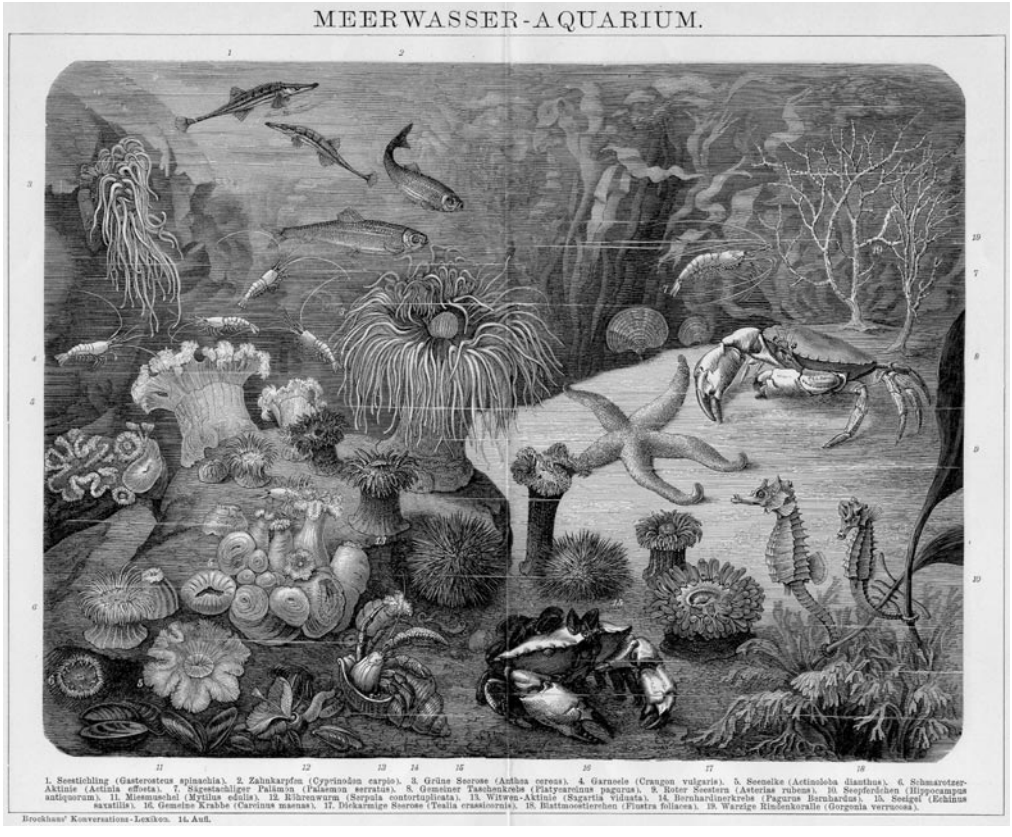
"Saltwater aquarium." From *Brockhaus' Konversations-Lexikon*, 14th ed. (1891).

temologically significant topos—marine animals, as long as they were in water, were considered to be always *at home*.

Many recent cultural-historical accounts of popular interest in aquariums recognize an anthropomorphizing tendency in the ubiquitous discourse concerning the "being-at-home" (*Daheim-Sein*) of living creatures in aquariums—an appropriation and inscription of nature into bourgeois ways of life. "In the salon and living room, center of bourgeois existence," the aquarium seemed to offer, in its proximity to "ivory figurines, orientalist statues of Moors, and Gothic bedrooms . . . a touch of contact with a surrogate for nature in the middle of the city."[50] Some authors have suggested that the rhetoric of the home as a metaphor for animal habitats says more about the bourgeoisie than about contemporary biology.[51] Certainly, the glass "ocean on the table" may be accurately described as a part and an extension of bourgeois interiors, justifying the assumption that discourse about animals being "at home" in the metropolitan salon is charged with the attribution of bourgeois morals and values to nature. However, close observation of the discourse surrounding aquariums reveals that the notion of the aquarium as a simulation of a "peaceful and intact world" does not suffice.[52] Rather, the concept of marine animals' "being-at-home" indicates that aquarists were involved in the generation of knowledge about the home: while studying the glass aquariums in their living rooms and studies, they drove the development of practical ecology, the study of the household or home indicated by the combined concepts of the Greek *oikos* and *logos*. Thus, when zoologist Bruno Dürigen, in the first issue of *Blätter für Aquarien- und Terrarien-Freunde*, reminds his readers that many of the open-ended research questions of aquatic biology could "only be solved by observing the object carefully in its domesticity," he means this not in terms of the living room but the *oikos* of the organisms under consideration.[53]

The *Blätter für Aquarien- und Terrarien-Freunde* published, in addition to articles about individual species, mostly contributions by aquarium lovers with titles such as "On some attempts to repel algae in aquariums using copper sulfate," "My aeration device," or "A new warm-water heater for aquariums."[54] In its pages, biological laypeople exchanged knowledge about the chemical composition or oxygen content of water, technical refinements of pump systems, or suitable parasite control strategies. As was obvious to anyone who had bought an aquarium, putting a fish in a water tank, thus providing it with its own material medium, was not enough to provide the animal a "home."

The ecological concept of the milieu that circulated among aquarium practitioners in the decades around 1900 went far beyond the mechanical notion



of the "medium," which holds that water alone is the "milieu" of the fish that moves through it.[55] The establishment of a "natural" milieu could not be achieved simply by filling a glass box with water. Much more important was the skillful fabrication of a complex network of "neighborhoods" that would, ideally, exhibit a "balance between animal and plant organisms," water, air and light, glass, cement, and many other materials, requiring a combination of technical interventions, regulatory knowledge, and knowledge of surroundings.[56] Establishing a robust milieu that would secure animals' long-term survival and enable their reproduction had less to do with replicating nature in a way that looked deceptively real; rather, as an English handbook stated, it involved a simulation of nature "not in outward appearances . . . but in conditions."[57] Animals are "at home" not because it looks to them like they are, but because their environments are structurally similar, because a well-designed aquarium provides them the "normal conditions" of their lives.[58]

In any case, interest in marine organisms did not occur without a parallel interest in their environments. In respect to this ecological perspective, formative for amateurs and experts alike, the scientific study of biology and popular aquarium studies were intertwined "in such a way that . . . many points of contact, even areas of overlap, arose," as Paul Kammerer remarked in a lecture at the Berlin aquarium club Triton.[59] Their mutual development stemmed primarily from the fundamentally experimental nature of both water biology and popular aquarium and terrarium studies. Kammerer did not understand experiments in the sense of "the vivisections of physiologists and pathologists," which he claimed

> are always synonymous with the destruction of the organisms subjected to them; in contrast, experiments which characterize the practices of modern biology involve, especially at their outset, certain disturbances which, however, must not destroy, but rather secure the well-being of laboratory animals and plants for generations; yes, only in the latter case may the experiment be described as completely successful. This implies a convergence of the goals of experimental biology with vivarium studies: for only those animals and plants which have a certain resistance to changes in their external living conditions, and therefore, are able to be held successfully in captivity, are appropriate for biological experimentation.[60]

To carry out such experiments, one had to "have undergone the necessary technical training to maintain an aquarium or terrarium in order to understand how to provide the animals and plants therein the conditions for their existence."[61] This lengthy, often tedious and time-consuming process of setting up and maintaining an aquarium that characterizes the work of hobby aquarists was usually unfamiliar to biologists, who too often understood this process merely as a cumbersome preparation of their objects of knowledge and a time-wasting precondition for their research activities:

> The most elementary concepts concerning the establishment of a container, the conditions for nourishment and the like—which even the rookie aquarium or terrarium owner has internalized in body and soul—are often unknown to the scholar; he witnesses, therefore, many of his experiments fail right from the start, where a vivarium amateur, without encountering the slightest difficulty, would have reared generations of the same animals or plants under the desired conditions.[62]

Experimental biology was thus "*directly dependent*" on knowledge produced through amateur aquarium and terrarium studies.[63]

The reassessment of the role of the aquarium enthusiast is therefore mainly due to the increasing focus in marine biology since the mid-nineteenth century on experiments with living organisms, which necessarily required the acquisition of environmental knowledge to transfer them to aquariums and terrariums and keep them alive. Aquarium enthusiasts had chosen to produce and care for these "self-regulating world[s] in miniature" as a hobby and thereby acquired practical knowledge that was of increasing value to academic biology.[64] This experiential knowledge resonated with the discipline's new research agendas, which increasingly attended to relationships between organism and environment. The aquarium enthusiast was accordingly reconsidered as a "serious, biologically minded caretaker," who,

"without knowing or wanting to, [advances] into the scientific field, from which he formerly stood—for reasons of principle—far away."[65]

Proliferating Milieus

In 1902, the Biologische Versuchsanstalt (Institute of Experimental Biology), also called the Vivarium (and formerly a public aquarium), where Kammerer also worked, was founded in the Vienna Prater through an initiative led by Przibram, Wilhelm Figdor, and Leopold von Portheim.[66] The purpose of the research institute was "to foster the experimental branches of biology, in particular those oriented . . . toward testing the dependence of morphological form on conditions of various kinds, recently described by Roux as developmental mechanics, by Davenport as experimental morphology."[67] Here again, the aquarium appeared at the center of the research complex. "Every workstation includes an electric study lamp, marine and freshwater aquariums, and terrariums; in addition, every worker has at their disposal beyond the stations convenient workspaces, aquariums, terrariums, and equipment available for experimental purposes."[68]

After five years, Przibram, as director of the institute and head of the zoological department, gave a detailed report on the "purpose, organization, and operation" of the Vivarium, the third section of which, titled "Living Material and Its Care," he devoted to the basis of the experimental biological work carried out there.[69] The text makes clear how much the establishment of an aquarium was indeed a techno-ecological operation aimed at producing an "environment" (*Umwelt*), but it likewise demonstrates the structural interminability of this undertaking. The "surroundings" (*Umgebungen*) and the "circumstances" (*Umstände*) constantly proliferate. The painstakingly built and stabilized milieus find no end—not at the glass walls that supposedly encase them, nor even at the walls of the rooms beyond.

This process begins simply enough at first: for the biologist who undertakes lengthy test series, it is, according to Przibram,

> inevitably necessary to offer the animals conditions that are as natural as possible. As a result, it is of paramount importance for every experimenter to obtain their test animals personally, to pay close attention to the circumstances under which the animals live in the wild, and to consider them accordingly.[70]

But what are these "circumstances" exactly? "Generally valid regulations" were difficult to establish in this regard "due to the high specialization of circumstances"; attention had to be paid to the correct type of water and, in the case of sea animals, to ventilation and flow.[71]

But the organism's milieu did not simply coincide with its medium of water. Plants belong to the milieu, as well as soil, which, as Przibram remarked, should ideally "also be sourced from the find site."[72] For freshwater animals, especially for the inhabitants of stagnant water, "the establishment of a water's edge" was also deemed appropriate.[73] Therefore, the use of entire "construction kits" was proposed so that sand, mud, pebbles, and larger stones could be used to shape the natural environments of laboratory animals in small glass cuboids in such a way that they could survive, reproduce, and serve scientific research as "living material."

It is not surprising that the aquariums were designed with such a keen eye for detail when one focus of the research at the Institute of Experimental Biology was the "observational study of living objects, not only in any surrounding but rather variations through analysis of individual factors integrated within the networks of relationships that form the living world."[74] Therefore, milieus had to be studied very carefully in order for conclusions to be drawn after the systematic modification of individual elements.

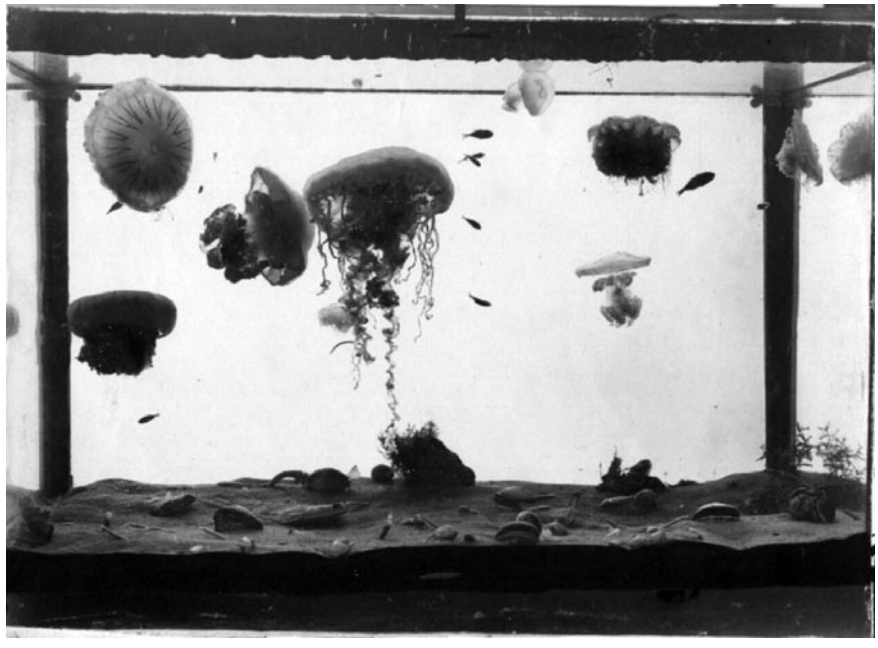
Marine biology thus perceived milieus as consisting of much more than material elements. Figures such as Taine, Comte, and Émile Durkheim had already discussed the milieu as a social category. Following this line of thinking, an organism's milieu was also understood to include other organisms that had to be considered in order for an environment to be produced. However, all of these additional creatures were also surrounded by their own further milieus. Do each and every one of these have to be accounted for? Where do the surroundings that the organism needs for survival actually end? What are the boundaries of a milieu? For Przibram and many of his colleagues, it was clear that these boundaries were hardly coterminous with the glass or stone walls of the aquarium. As they were well aware, the "research milieu" also played a role in the stabilization of aquatic milieus in a very concrete sense: the space in which tanks were located was also integrated into the fragile system of "neighborhoods." This idea informs Przibram's statements in the institute's activity report for 1908–1912 that deal with the physical building of the Institute for Experimental Biology, which actually functioned as a "vivarium." He writes about special copper boilers for gas firing, about generators, ventilators, air pressure bells, temperature chambers and their isolation—technologies that enabled "the Vivarium's precision-controlled environments" and at the same time made it recognizable as such an environment.[75]

Due to changing biological research perspectives, many zoological institutes had been established in German-speaking countries since the end of the nineteenth century, though only in rare cases with the financial and techno-

Skylight and large, dark aquariums, Biologische Versuchsanstalt (Institute of Experimental Biology), Vienna, ca. 1910. Archive of the Austrian Academy of Science, Biologische Versuchsanstalt (Vivarium), K. 4.4.

logical possibilities available at the Institute of Experimental Biology. The Zoological-Zootomic Institute of the University of Würzburg, for example, was rebuilt to accommodate the new tasks of experimental biology "because the way in which a new building is arranged reveals the type and direction of the scientific research that is to be undertaken there: the building becomes, in a certain way, the embodiment of prevailing ideas."[76] Thus, one looked from Lower Franconia toward the sea "at a time," wrote the institute's scientific assistant, August Schuberg, "when marine zoological stations have been founded all over and even freshwater stations have begun to appear. It is astonishing that most of the university institutes involved in research work offer very few opportunities for observing or breeding even native animals." The main principle of the organization was therefore "to create the necessary conditions for this in the construction of the local institute."[77] A hothouse was built to house aquariums, terrariums, and cages, as well as a garden including an aviary and other aquarium tanks. What Przibram called "environments" or "circumstances" were named "atmosphere" by Schuberg and, as was the case at the Vivarium and elsewhere, this was achieved via modern regulatory technologies—from heaters and fans to foundries and systems of water circulation.[78]

The milieus created in the aquariums of life-science research institutions around the turn of the century expanded systematically beyond the glass walls, which provided merely the semblance of limits. This expansion made the "automatic regulation" of the institutes' rooms necessary and thus implicated them in the milieus of the organisms studied there.[79] The notion of the "self-regulating world in miniature" encompassed not only the aquarium but also the laboratory itself.[80] At many institutions devoted to the dissemination of natural scientific knowledge, this proliferation of milieus—the never-ending cascade of interconnected, interdependent environments—became a source of failure. At the Berlin Museum of Oceanography, for example, aquariums that had been exhibited there for some time had to be removed: the milieu of the museum visitor was not that of the ocean inhabitant—the air too dry, the light too bright. In their stead, so-called alcoholariums were



installed—glass cases filled with dead marine animals swimming through oceans of alcohol (or rather, affixed to transparent wires keeping them in place). The audience now had, on the one hand, "habitats" (*Lebensräume*) presented before their eyes and, on the other, the complexity of networked ecological relationships.

While the phantasm of framing a milieu without an environment seems to have materialized in aquariums, their use demonstrated the impossibility of such an idea time and time again. Attempts at limiting the proliferation of milieus could be carried out only through conceptual work. Terminological limits were enlisted to contain proliferating milieus, giving them contours and boundaries as environments (*Umwelten*) and surroundings (*Umgebungen*), habitats (*Lebensräume*) and living areas (*Lebensbezirke*), biotopes (*Biotope*) and ecosystems (*Ökosysteme*). The transformation and differentiation of these concepts represented the dynamics of the objects of knowledge in question. The materiality of marine biological research and the formation of such concepts developed in productive interrelationship, with the aquarium serving as the material fulcrum of intellectual movements that proved to be both systematic openings and terminological closures. The aquarium functioned as a frame with the task of "mediating divisions and connections"[81] between the artificially stabilized milieus within and beyond its walls, thus contributing significantly to the generation of environmental knowledge and to the enhancement of ecological concepts.

"Medusae of the North Sea," in alcohol, Museum für Meereskunde (Museum of Oceanography), Berlin, ca. 1907. Deutsches Technikmuseum Berlin, photo collection "Museum für Meereskunde," Q 07 035.

Notes

1. Konrad Lorenz, "Laudation" (unsigned), 26 March 1980, in Konrad Lorenz Archive, Konrad Lorenz Haus, Altenberg, Austria.

2. Lorenz.

3. Jakob von Uexküll, *Leitfaden in das Studium der experimentellen Biologie der Wassertiere* (Wiesbaden: Bergmann, 1905), 11.

4. Uexküll, *Leitfaden*, 12.

5. Uexküll, *Leitfaden*, 76.

6. Jakob von Uexküll, *Bausteine zu einer biologischen Weltanschauung* (Munich: Bruckmann, 1913).

7. Jakob von Uexküll, *Theoretische Biologie* (Berlin: J. Springer 1928), 62.

8. Kijan Malte Espahangizi, "Wissenschaft im Glas: Eine historische Ökologie moderner Laborforschung" (Ph.D. diss., ETH Zurich, 2010), 10.

9. Georges Canguilhem, "The Living and Its Milieu," *Grey Room*, no. 3 (Spring 2001): 7.

10. Compare Julius Zeitler, "Taine und die Kulturgeschichte," *Philosophische Studien* 20 (1902): 670–712.

11. Lynn K. Nyhart, *Modern Nature: The Rise of the Biological Perspective in Germany* (Chicago: Chicago University Press, 2009).

12. Nyhart, 125.

13. Nyhart, 135–36.

14. Nyhart, 138.

15. Karl Möbius, "Einige Fingerzeige für die Bevölkerung und Erhaltung der Aquarien," *Der zoologische Garten: Zeitschrift für Beobachtung, Pflege und Zucht der Thiere* 4, no. 6 (1865): 211–14, 212.

16. Conrad Keller, *Das Thierleben in großen Meerestiefen* (Basel: Schweighauserische Verlagsbuchhandlung, 1883), 3–4. For an overview of the exploration of the deep sea in the nineteenth century, see Helen Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea* (Cambridge, MA: Belknap Press of Harvard University Press, 2005).

17. Gustav Jäger, *Das Leben im Wasser und das Aquarium* (Stuttgart: Franckh'sche Verlagshandlung, n.d.), 164.

18. As late as 1925, Kurt Floerike describes marine organisms as "fairytale creatures": Kurt Floericke, *Wundertiere des Meeres* (Stuttgart: Franckh'sche Verlagshandlung, 1925), 5.

19. Jäger, 166; and Johannes Walther, *Allgemeine Meereskunde* (Leipzig: Verlagsbuchhandlung J.J. Weber, 1893), preface.

20. Georg Hartwig, *Das Leben des Meeres: Eine Darstellung für Gebildete aller Stände* (Glogau [Głogów]: Verlag Carl Flemming, 1862), 10.

21. Möbius, 212.

22. Adolf Steuer, "Die Entwicklung der zoologischen Stationen," *Die Naturwissenschaften* 4 (1926): 283.

23. Guido Findeis, *Das Aquarium und seine Bewohner: Eine Anleitung zur Herstellung und Pflege desselben* (Vienna: self-published, 1883), 2.

24. "Wie er- und behält man den Ocean auf dem Tische, oder das Marine-Aquarium," *Die*

Gartenlaube 38 (1855): 504.

25. For the British and German histories of the aquarium especially, see Mareike Vennen, *Das Aquarium: Praktiken, Techniken & Medien der Wissensproduktion (1840–1910)* (Göttingen: Wallstein, 2018).

26. See also Christian Reiss, "Gateway, Instrument, Environment: The Aquarium as a Hybrid Space between Animal Fancying and Experimental Zoology," *NTM* 20, no. 4 (2012): 309–36.

27. See Bernardino Fantini, "The 'Stazione Zoologica Anton Dohrn' and the History of Embryology," *International Journal of Developmental Biology* 44 (2000): 523–35.

28. Hans Przibram, lecture manuscript, 9 May 1935, in Archive of the Austrian Academy of Sciences (AÖAW), Biologische Versuchsanstalt (Vivarium), K1/M1, I.4/4.

29. Chancey Juday, quoted in Steuer, 5.

30. Anton Dohrn, cited in Hans Zimmermann, "Einrichtungen und Methoden bei der Akklimatisation der Meerestiere," *Blätter für Aquarien- und Terrarienkunde* 14, no. 19 (1903): 260. Zimmermann's article was published across three issues of the journal, all in vol. 14 (1903): no. 19, pp. 259–62; no. 20, pp. 278–80; and no. 21, pp. 290–92.

31. Anton Dohrn, "The Foundation of Zoological Stations," *Nature* 5, no. 119 (8 February 1872): 279.

32. Dohrn, "The Foundation of Zoological Stations."

33. "Die deutsche zoologische Station in Neapel," *Blätter für Aquarien- und Terrarienkunde* 14, no. 6 (1903): 76.

34. Uexküll, *Bausteine*, 120–21.

35. "Die deutsche zoologische Station in Neapel."

36. Carl I. Cori, "Erklärung der k.k. Zoologischen Station in Triest betreffs Abgabe von Seetieren, -Pflanzen und -Wasser an private Liebhaber," *Blätter für Aquarien- und Terrarienkunde* 19, no. 45 (1908): 648.

37. Zimmermann, 261.

38. Paul Kammerer, "Aquarien- und Terrarienausstellung des Vereins 'Lotus' in Wien 1908," *Blätter für Aquarien- und Terrarienkunde* 19, no. 43 (1908): 604.

39. Zimmermann, 262.

40. Zimmermann, 262.

41. Zimmermann, 278.

42. Zimmermann, 278.

43. Cori.

44. Cori.

45. Zimmermann, 278; and Cori.

46. Guido Findeis, *Illustrirtes Preis-Verzeichniß von Aquarien, Terrarien, Pflanzen und Luxusfischen* (Vienna: self-published, 1883), 54, fig. 43.

47. From 1902, the journal was retitled *Blätter für Aquarien- und Terrarienkunde* (Papers for aquarium and terrarium studies). On media, associations, and other popularization activities, and the differences between the German "Aquarienkunde" project and the English "aquarium craze," see Reiss.

48. Shirley Hibberd, *The Book of the Aquarium and Water Cabinet; or, Practical Instructions*

on the Formation, Stocking, and Management, in All Seasons, of Collections of Fresh Water and Marine Life (London: Groombridge and Sons, 1856), 6.

49. Canguilhem also thinks of the aquarium when he explicates the physical definition of the concept of milieu: "it is in a purely mechanical sense that one says that water is a milieu for the fish who move around it." Canguilhem, 9.

50. Bernd Brunner, *Wie das Meer nach Hause kam: Die Erfindung des Aquariums* (Berlin: Wagenbach, 2011), 89.

51. Compare, for example, Isabel Kranz, "'Parlor Oceans,' 'Crystal Prisons': Das Aquarium als bürgerlicher Innenraum," in Thomas Brandstetter, Karin Harrasser, and Günther Friesinger, eds., *Ambiente: Das Leben und seine Räume* (Vienna: Turia+Kant, 2010), 162.

52. Brunner, 125.

53. Bruno Dürigen, "An die Leser!," *Blätter für Aquarien- und Terrarien-Freunde* 1, no. 1 (1890): 2. The related etymology of *oikonomia* and *dispositif* is discussed in Giorgio Agamben, "What Is an Apparatus?" in *What Is an Apparatus? And Other Essays*, trans. David Kishik and Stefan Pedatella (Stanford: Stanford University Press, 2009), 1–24.

54. Hugo Hackenberg, "Ueber einige Versuche, Algen in Aquarien durch Kupfersulfat zu vertrieben," *Blätter für Aquarien- und Terrarienkunde* 19, no. 40 (1908): 554–56, no. 41 (1908): 570–72, and no. 42 (1908): 586–89; Leonh. Nüssler, "Meine Durchlüftungsanlage," *Blätter für Aquarien- und Terrarienkunde* 21, no. 10 (1910): 153–54, and no. 11 (1910): 170–71; and J. Ehlers, "Eine neue Warmwasserheizung für Aquarien," *Blätter für Aquarien- und Terrarienkunde* 20, no. 16 (1909): 253–55, and no. 17 (1909): 263–65.

55. See John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media* (Chicago: University of Chicago Press, 2015), esp. ch. 2, which revolves around water.

56. [C.] Kerbert, "Ein Beitrag zur Geschichte des Aquariums," *Blätter für Aquarien- und Terrarienkunde* 17, no. 29 (1906): 293. The first part of Kerbert's article was published in vol. 17, no. 27 (1906): 270–71.

57. Shirley Hibberd, *Rustic Adornments for Homes of Taste*, new ed. (London: Groombridge and Sons, 1870), 47.

58. Uexküll, *Leitfaden*, 76.

59. Paul Kammerer, "Die Aquarien- und Terrarienkunde in ihrem Verhältnis zur modernen Biologie," *Blätter für Aquarien- und Terrarienkunde* 16, no. 9 (1905): 84. Kammerer's article continues in vol. 16, no. 10 (1905): 94–96. Remarkably, although there were assistants at most of the biological and zoological institutes, Kammerer notes that the maintenance and care of aquariums apparently belonged to the core business of the scientists themselves. This makes clear that the ecological "component" of the activity of biologists was not just outsourced or given away, but was understood as an integral part of the research process.

60. Kammerer, "Die Aquarien- und Terrarienkunde in ihrem Verhältnis zur modernen Biologie," 84.

61. Kammerer, "Die Aquarien- und Terrarienkunde in ihrem Verhältnis zur modernen Biologie," 94. Many of the constellations that have been described as the starting point for generating ecological knowledge apply, as Kammerer's text suggests, to both aquariums and terrariums. The former, however, played an even more specific role in the differentiation of knowledge of surroundings.

62. Kammerer, "Die Aquarien- und Terrarienkunde in ihrem Verhältnis zur modernen Biologie," 94.

63. Kammerer, "Die Aquarien- und Terrarienkunde in ihrem Verhältnis zur modernen Biologie," 94.

64. Kammerer, "Die Aquarien- und Terrarienkunde in ihrem Verhältnis zur modernen Biologie," 84.

65. Hermann Labonté, "Die öffentlichen Aquarieninstitute und die Aquarien- und Terrarienkunde," *Blätter für Aquarien- und Terrarienkunde* 25, no. 18 (1914): 321; and [K.] Ullmann, "Aus dem Arbeitszimmer des Aquarikers," *Blätter für Aquarien- und Terrarienkunde* 20, no. 2 (1909): 17.

66. Compare Wolfgang L. Reiter, "Zerstört und vergessen: Die Biologische Versuchsanstalt und ihre Wissenschaftler/innen," *Österreichische Zeitschrift für Geschichtswissenschaften* 10, no. 4 (1999): 585–614; and Veronika Hofer, "Rudolf Goldscheid, Paul Kammerer und die Biologen des Prater-Vivariums in der liberalen Volksbildung der Wiener Moderne," in Mitchell G. Ash and Christian H. Stifter, eds., *Wissenschaft, Politik und Öffentlichkeit: Von der Wiener Moderne bis zur Gegenwart* (Vienna: WUV Universitätsverlag, 2002), 149–84.

67. "Kommissionsbericht der Akademie der Wissenschaften in Wien," in AÖAW, Biologische Versuchsanstalt (Vivarium), K1/M1.

68. "Arbeitsordnung (Ordnungsbestimmungen) für die Benützung der Arbeitsplätze an der Biologischen Versuchsanstalt in Wien," 1 January 1913, in AÖAW, Biologische Versuchsanstalt (Vivarium), K1/M1, A. 1/1.

69. Hans Przibram, "Die Biologische Versuchsanstalt in Wien: Zweck, Einrichtung und Tätigkeit während der ersten fünf Jahre ihres Bestandes (1902–1907), Bericht der zoologischen, botanischen und physikalisch-chemischen Abteilung. (1. Fortsetzung)," *Zeitschrift für biologische Technik und Methodik* 1, no. 3 (1908): 329.

70. Przibram, "Die biologische Versuchsanstalt in Wien" (1908), 334.

71. Przibram, "Die biologische Versuchsanstalt in Wien" (1908), 332–33.

72. Przibram, "Die biologische Versuchsanstalt in Wien" (1908), 331–32.

73. Przibram, "Die biologische Versuchsanstalt in Wien" (1908), 336.

74. Przibram, lecture manuscript.

75. Deborah R. Coen, "Living Precisely in Fin-de-Siècle Vienna," *Journal of the History of Biology* 39, no. 3 (Autumn 2006): 506. And see Hans Przibram, "Die Biologische Versuchsanstalt in Wien: Ausgestaltung und Tätigkeit während des zweiten Quinquenniums ihres Bestandes (1908–1912), Bericht der zoologischen, botanischen und physikalisch-chemischen Abteilung," *Zeitschrift für biologische Technik und Methodik* 3, no. 4–5 (1913): 163–245. Kijan Espahangizi speaks of "laboratories as environments of experimental research" and as the starting point for a "historical ecology of modern laboratory research." In his study, he structurally examines the "historical development of laboratory ecological functional circles [Funktionskreise]," which is also of importance for the architectural setup of experimental biological institutes. Espahangizi, "Wissenschaft im Glas," 2–3.

76. August Schuberg, "Das neue zoologisch-zootomische Institut der Königlichen Julius-Maximilians-Universität zu Würzburg," in *Arbeiten aus dem Zoologisch-Zootomischen Institut in Würzburg*, ed. Carl Semper, vol. 10, pt. 1 (Wiesbaden: C.W. Kreidel's Verlag, 1891),

3. Compare Reiss, esp. 323–25.

77. Schuberg, 5.

78. Schuberg, 8.

79. Przibram, "Die biologische Versuchsanstalt in Wien" (1913), 177.

80. Kammerer, "Die Aquarien- und Terrarienkunde in ihrem Verhältnis zur modernen Biologie," 84.

81. Georg Simmel, "Der Bilderrahmen: Ein ästhetischer Versuch," in *Zur Philosophie der Kunst: Philosophische und kunstphilosophische Aufsätze von Georg Simmel*, ed. Gertrud Simmel (Potsdam: Gustav Kiepenheuer Verlag, 1922), 54.