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Architecture before architecture: Frei Otto's 'Deep History'

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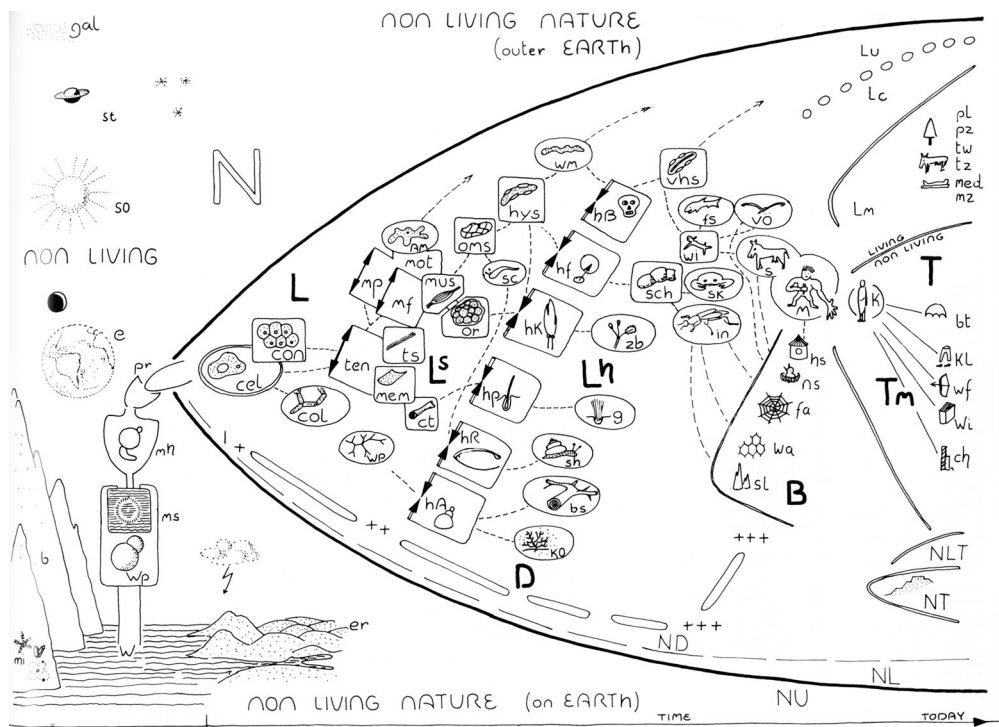
The German architect Frei Otto was deeply concerned with the environmental crisis caused by the presence of humans on earth. Otto responded to this by investigating the origins, and potential futures, of architecture through the lens of natural history. This paper will focus on the significant collaboration between Frei Otto and the German biologist and anthropologist Johann-Gerhard Helmcke (1908–1993). Their collaboration began in the early 1960s, and can be largely credited for Otto's interest in biology and his appropriation of scientific methodology. Helmcke's anthropological work also influenced Otto's understanding of the role of humans in creating architecture and the environment. Otto and Helmcke developed a theory of bio-technics based on measuring and calculating the structural properties of plants, animals and even human bodies. Eventually, they invented a cosmology of objects that extended to all forms, whether living or non-living, natural or technological—including architecture.

Helmcke argued that 'if we want to comprehend the concept "nature" in as pure a way as possible, we must refer back to that prehistoric period when there were as yet no people to intervene in the natural equilibrium'. By directly testing materials that included hair, bones, spider webs and seashells, Otto looked for structures that corresponded to what can be described as 'an architecture before humans'. At an historical moment in which modernist narratives of progress and the domination of nature came increasingly under question, Otto sought alternative means to construct the development and history of form. What are the problems raised in this renewed search for the origins of architecture? Did Otto's quest for structural optimisation in nature simply introduce another anthropocentric narrative? This paper will examine these and other contradictions in Frei Otto's relationship to the architecture of the pre- and un-human.

In a cartoon-like drawing published in 1977, entitled 'On the Evolution of the World of Forms of Living Nature', the German architect Frei Otto shows what appears to be either an evolutionary tree or table of elements, which floats in a landscape divided into three general categories: 'Non-Living Nature' (N), 'Living Nature' (L) and 'Technology' (T) (Fig 1).¹ Otto was trying to chart the relationships between all animate and inanimate forms, begin-

ning with atoms and molecules and ending with, amongst other things, architecture. Human beings, and what they produce, appear only after the long process of the creation of life. When a human being appears in the chart, it shares evolutionary territory with some sort of mammal, possibly a goat, and holds a tool in one hand whilst stretching out the other hand, which is considerably oversized. The human is seen as linked to a small hut, described

Figure 1. Frei Otto, 'On the Evolution of the World of Forms of Living Nature', IL 9: *Pneus in Nature and Technics* (1977).



as 'houses, large envelopes of collected matter, man, beaver' (hs), which is grouped with other animal-built technologies such as nests, spider webs, bee colonies and termite mounds (B). But the human hand extends towards a number of things it has created: 'living nature' such as agriculture, artificial landscapes, animal breeding and medicine, and the technology of man related to the 'fine arts' (K), which includes clothing, weapons, scientific research and 'construction tech-

nology' (bt), represented by a small drawing of a domed membrane structure. This, it seems, is where modern architecture might belong.

In this alternative cosmology that at once combines natural history and the history of technology, human architecture appears at a node in the drawing where the boundaries between the categories of human, animal, nature and technology split into several directions. On the one hand, the architecture of the human being is compared to



Figure 2. Frei Otto (left) with Eberhard Haug: pneumatic experiment with inflated animal intestines, 1973 (ILEK Archive).

that of the animal—it is a collection of matter not unlike that of a nest or termite mound—on the other hand, the human is also the creator of another sort of architecture, derived not from its animal nature but from art and technology, or as Otto puts it, the ‘the world of forms of nature made or influenced by human activity’.²

Tracing and crossing the boundaries between these forms of architecture—living and non-living, animal and technological—was a central theme of Otto’s career (Fig. 2). In doing so Otto challenged the role

of the human being as the privileged creator of the built environment. It is clear that the human is not at the centre of Otto’s natural history; however, his overdeveloped hand is shown as having had a profound effect on its course. As Otto puts it: ‘In relationship to animate nature, technology is still undeveloped. It knows some extreme development peaks in very specialised fields. Man can fly to the moon, but cannot yet solve problems of wholeness.’³ Wholeness in architecture would come about only through a synthesis of these disparate evolutionary

moments in natural history: 'We have not yet experienced the fragile, perhaps even ephemeral, architecture of the physical and psychical integration of man into his environment. But we seek the architecture of understanding and of the great vision of a synthesis of all the objects of nature.'⁴

In his search for alternatives to the disproportionate effect that humans have had on the earth's living and non-living structures, Otto created what I will argue is a sort of architectural prehistory. This refers not just to the history of human structures before written history (which were also of interest to Otto), but more radically to a natural history of forms and structures that existed before, and in spite of, human activity.

Otto's interest in the intersections between prehistory and natural history was part of a more general approach that had already emerged in the 1960s, in the form of what Robert Smithson called, in 1967, a 'trans-historical consciousness'.⁵ This ranged from a fascination with prehistory to a new cosmological and planetary perspective on life. It is evidenced in the art historian George Kubler's *The Shape of Time* (1962) and its focus on objects rather than human narratives, and in Siegfried Giedion's attempts to establish a prehistory for architecture in the two volumes of *The Eternal Present* (1962; 1964).⁶ This consciousness emerged at the same time in popular culture, as seen in the famous 'four-million-year jump cut' in Stanley Kubrick's *2001: A Space Odyssey* (1968), where a femur bone flung in the air by a primate, who had just used it as a brutal weapon, transitions to a spacecraft floating through deep space. Both the Cold War and the emerging environmental movement had raised the spectre of the destruction of the

earth and human species as a whole, suggesting that there could one day be an *end* to history. For Otto and others, the trans-historical search for origins seemed to be an alternative to the destructive tendencies of the modern, Western model of technological progress. At the same time, this turn to cosmic scientific utopianism, and idealised notions of the primitive, were very much products of the privileged position of universal reason in Western societies.⁷

In recent years there has been renewed interest in looking at the long span of the Earth, the history of human beings and the effect humans have had on the Earth. Discussions around globalisation have contributed to the return to this view; but it can be traced more directly to the awareness of a planetary crisis. The concept of the Anthropocene that emerged from this has led to existential discussions on the possibility of a world 'without us', as well as political calls for environmental accountability.⁸ Another idea reflecting this vein is 'Deep History' which proposes that we consider an historical *longue durée* that includes crossing, and erasing, the threshold of what is otherwise known as prehistory.⁹ Endorsing this expanded temporal scope, the historian Dipesh Chakrabarty has recently called for the collapse of the long-standing division between human history and natural history.¹⁰ 'Climate change', he wrote, 'shows ... the effects of our actions as a species. Species may indeed be the name of a placeholder for an emergent, new universal history of humans that flashes up in the moment of the danger that is climate change.'¹¹

Chakrabarty makes this speculative claim with a great many caveats, but the cat has been let out of the bag: he suggests that the diversity of human

histories be reduced to a universal, biological conception of the human. In spite of the troubling biopolitical connotations of this idea of 'species thinking', the potential catastrophe that is the result of our actions within the Anthropocene seems to have inspired both a post-humanist version of history, and, at the same time, a return to a deeper historical frame. These models of history not only displace the primacy of a human account of history, but also the human as the *subject* of history. They introduce the potential agency of matter, non-human actors and what Bruno Latour calls 'quasi-objects': the things in this world that condition social and material lives.¹² The Anthropocene, a concept defined by the impact of human beings on the planet, has, perhaps paradoxically, opened the possibility for a model of history that challenges human agency.

I Frei Otto's interest in trans-historical frameworks, which led him to investigate the origins, and the future, of architecture through the lens of natural history, was similarly tied to a deep concern with questions of man's planetary role. Otto is best known for his experiments in lightweight structures, but these were only part of his interest in the natural sciences. In fact, the greater proportion of the work at his Institute for Lightweight Structures (IL), founded in 1964, was dedicated to projects that focussed on biological themes. This meeting of architecture and biology can be largely attributed to Otto's decades of collaboration with the biologist and anthropologist Johann-Gerhard Helmcke.

In their understanding of structural form, human-built architecture plays only a small role in a general cosmology that includes molecules, planets, geological formations, plants, animals and animal-built structures such as nests and webs. Their model proposes continuity between what they call 'living' and 'non-living nature', a system of forms that evolve and devolve at different rates over time. Implicit in this model was an understanding of the destructive impact of human technology (including architecture) on the earth's environment, which would gradually become one of the primary reasons for the search for alternative structures in nature.

For Otto and Helmcke, nature did not simply serve as model or metaphor, but as direct material evidence for theories on the evolution of form and structure. Unlike art-historical approaches focused primarily on form, their investigations also encompassed questions of structural and material performance. The comparison of man-made structures with natural structures became the basis for an alternative model of history that extends far into prehistoric and pre-human time. Because Deep History includes events that pre-date written history, it relies on an alternative set of sources including material artefacts and the natural environment, but also the human body's genetic, chemical and morphological information. Similarly, in Otto's studies, the chemical, biological and evolutionary are taken into account, with the result that the history of architecture is inscribed into the *longue durée* of natural history.

The collaboration between Otto and Helmcke began in 1961. At the time, Otto was in Berlin running a tiny research 'institute' (the Institute for the Development of Lightweight Construction) out

of a shed in his in-laws' back yard, and working as a teaching assistant at the Technical University of Berlin. Until he met Helmcke, Otto was primarily concerned with the problem of structural lightness, which he investigated by measuring the behaviour of physical models and objects, the best known of which were made of soap film. Soap film forms a 'self-generated' structure of almost perfect optimisation, with a thickness of only a few molecules. In his 1953 dissertation on suspended roofs Otto had already suggested a relationship between self-formation and natural structures:

Hanging roofs cannot be designed. When every impure tone is avoided, one can help them unfold. They suggest a peculiar beauty that is perhaps closest to the plastic trace of the spider's web: an appearance that one cannot draw or explain, that will discreetly elude us.¹³

Otto's interest in the elusive forms created by chemical, biological or physical processes was directly related to his criticism of the 'brutality' of both fascist and modernist architecture, and its effects on the German landscape, which he would later describe as *Heimatzerstörung durch Häuser* ('homeland destruction through houses').¹⁴

Otto and Helmcke met at the Technical University of Berlin, where Helmcke was a professor of anthropology and biology. Helmcke was born in Hanover in 1908, and studied biology, anthropology, paleontology and philosophy in Berlin during the 1930s. Helmcke's areas of interest were vast, but he published mostly on the micro-structures of teeth and diatoms (microscopic algae enclosed in silica shells), producing entire atlases filled with images taken with an electron microscope that call to

mind Ernst Haeckel's aesthetic documentation of the similar silicified structures of radiolaria.

Otto and Helmcke's investigations into the natural history of structure began at the microscopic scale. Just as Otto had intuited that natural structures might provide key information for his idea of lightness, Helmcke's approach to micro-structures was architectural, even before meeting Otto. Helmcke took stereoscopic photographs of diatoms, which were used to give a 'spatially correct impression of the framework of the building elements'.¹⁵ This provided the basis for reconstructive drawings of these structures, with architectural conventions like plans, sections and renderings (figs 3a, 3b).

Helmcke was especially interested in the relationship between biology and engineering, and co-founded a research group in 1960 called 'Technology und Biology'.¹⁶ A seminal member of this group was the aeronautics engineer Heinrich Hertel, who published *Structure, Form, and Movement* in 1963, a bionic study of the fluid dynamics and structural properties of fish for aeroplane and ship designs.¹⁷ Several other books were influential for the group, including the typological studies in Curt Siegel's 1960 *Structural Forms of Modern Architecture* and publications by Konrad Wachsmann (especially his *The Turning Point of Building*, 1959) and Buckminster Fuller (Fig. 4).¹⁸ Architecture students began attending Helmcke's seminars, and soon Otto and Helmcke met and co-taught a seminar on biology and building, launching a collaboration that would continue until Helmcke's death in 1993. Later, the 'Natural Constructions' research team at the IL, a collaboration of botanists, palaeontologists, zoologists, biophysicists and behavioural

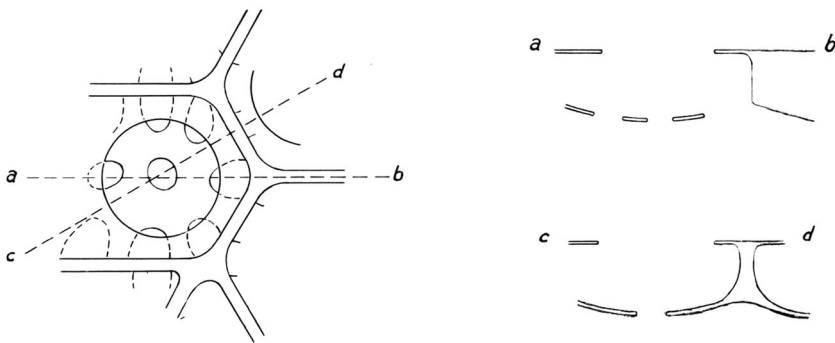
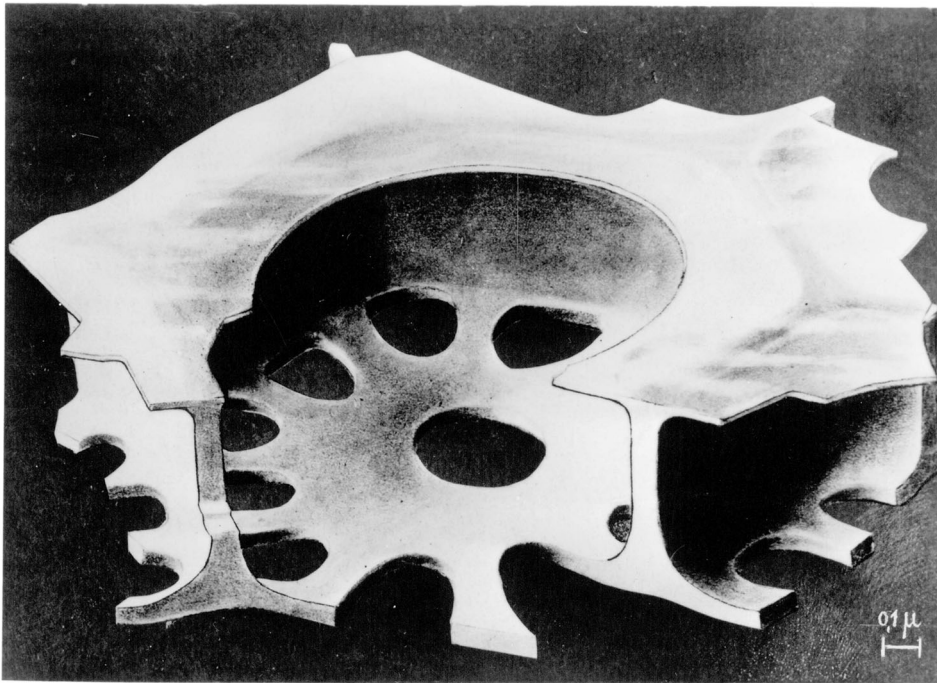


Figure 3a. Photogrammetric measurement and reconstructed drawing of a diatom: J.-G. Helmcke, W. Krieger, *Diatomeenschalen im elektronenmikroskopischen Bild*, vol. 1 (Weinheim, J. Cramer, 1962).

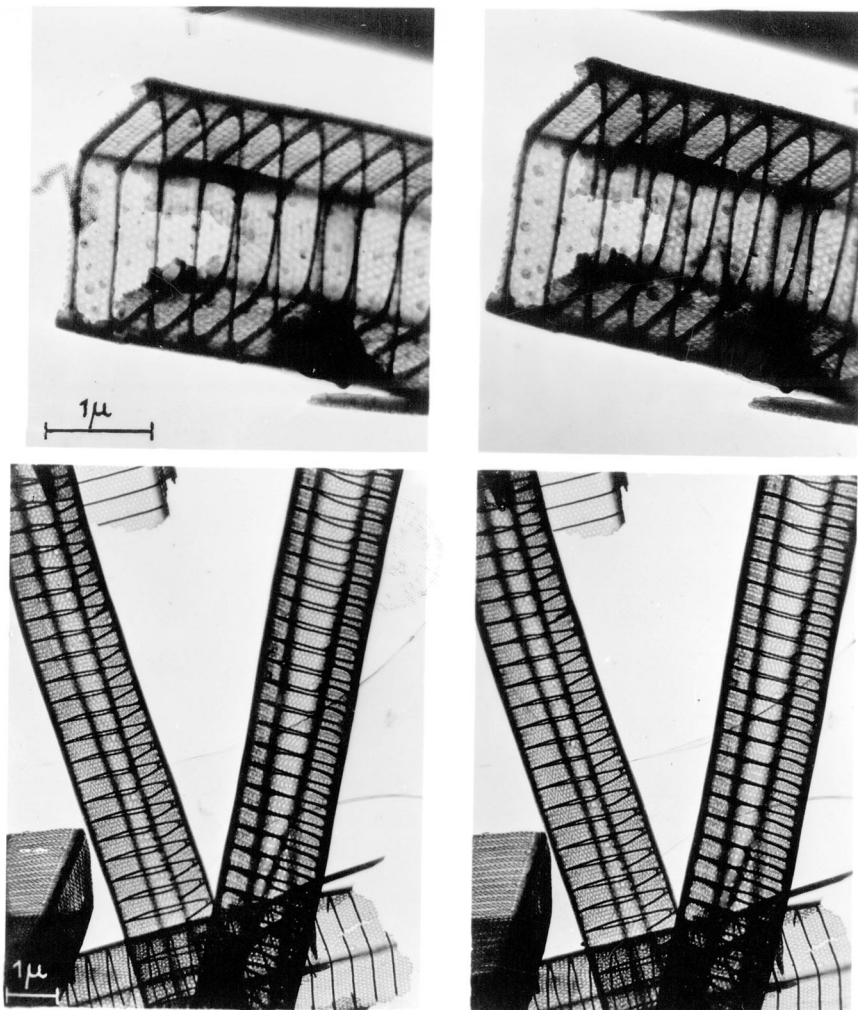


Tafel 29 *Actinocyclus Ehrenbergii Ralfs.*

oben: Photogrammetrische Ausmessung (Hans Richter)

unten: Rekonstruktionszeichnung einer Kammer (Kurt Bogen) 40 000:1

Figure 3b. Stereoscopic
photograph of a
diatom: J.-G. Helmcke,
W. Krieger,
*Diatomeenschalen im
elektronenmikrosk
opischen Bild*, vol. 2
(Weinheim, J. Cramer,
1962).



Tafel 121. *Chaetoceros borealis* **Bailey**

oben: Borste 15 000 : 1

unten: Borste 7200 : 1



scientists, continued the work of the 'Technology and Biology' group. In a letter to Otto in 1973, Helmcke wrote that, looking back over the last twenty-two years, their work together had been the 'most interesting and productive topic'.¹⁹

For Otto and Helmcke the world of nature and technology became subsumed under a general understanding of structure. It was seeing Helmcke's microscopic images of radiolaria that first suggested this universal structural principle to Otto:

Helmcke showed me his stereoscopic photographs of diatoms and radiolaria taken with an electron microscope. In these photos I saw shapes which had formed 'of themselves' in my experiments with pneumatics, i.e. soap bubbles, soap films, rubber membranes and net structures. From then on I saw only such forms in all living organisms, not only in diatoms.²⁰

What began as a morphological comparison between forms from separate realms—experimental architecture and microbiology—developed into a general study of structure that went beyond the

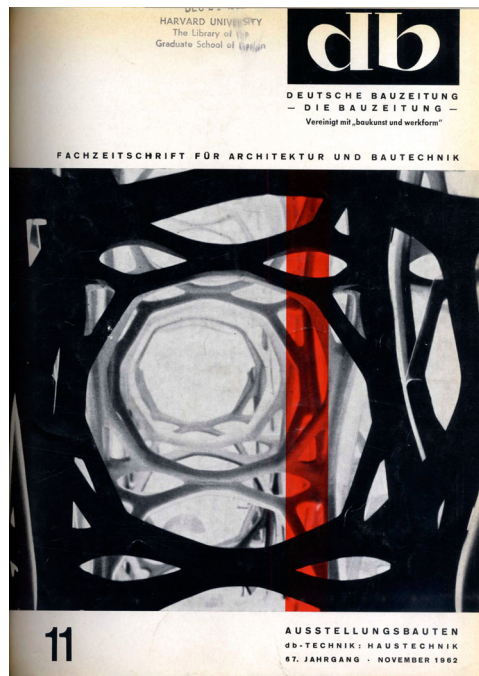


Figure 4. J. G. Helmcke, Buckminster Fuller, F. Otto at the IL; date unknown (ILEK Archive).

Figure 5. J.-G. Helmcke, Frei Otto, 'Lebende und Technische Konstruktionen. Bemerkungen zu Schalen und Raumtragwerken in Natur und Technik', *db deutsche bauzeitung*, 11 (1962).

comparison of appearances to focus on questions of materiality and performance. By isolating the single criterion of structural performance, Otto and Helmcke were able to insert architectural form into the evolutionary framework of natural history, and thereby suggest a history of architecture that includes prehistoric structures.

This crossing over between natural and human structures can be seen in their first co-published article in 1962, entitled 'Living and Technical Constructions: Observations on Shells and Spaceframes in Nature and Technology' (Fig. 5):

The far-reaching accordance between technical and living constructions can only now be observed as technical constructions have attained a higher level of accomplishment. The first constructions of early humans resemble the holes, nests, and designs of animals, but not at all the inner structure of living beings themselves, which already existed to a high level of perfection in prehistoric time.²¹

They go on to argue that it is only more recently that human structures have begun to 'catch up' with these more advanced prehistoric ones. This is an unusual version of the search for architecture's prehistory. Otto and Helmcke go beyond the 'primitive hut' approach according to which early human structures are closer to nature, and by extension, closer to the origins of architecture. Instead, the lowly diatom, one of the most primitive forms of life by evolutionary standards, is here celebrated for its extraordinary structural properties. The 'perfected' structure of the prehistoric, single-cell diatom offers a glimpse of what the future might look like, to which human architecture must still catch up. In other words: the prehistoric is architecture's future. This operates counter to the linear models of progress typically suggested by modernist architectural histories. As an example of what the future might hold, the authors compare images of diatoms with structures by Fuller and Pier Luigi Nervi.

The comparison between living and non-living structures is not limited to formal observations. Helmcke and Otto also address questions of purpose. Whilst in nature the process of selection is based on survival of the fittest, Helmcke and

Otto argue that in human-made structures fitness is based on the minimal use of material and energy. By loosening the definition of purpose for architecture—so that it is about economy and not function—it is brought closer to the purely structural realm that allows it to be compared to nature. There is still a difference between the purpose of architecture and that of nature—Otto and Helmcke explain that while a tree acts as a structural member (a column), it is also a living thing: 'a tree is not a tool for a living being, it is a living being itself'²²—but Otto and Helmcke suggest that perhaps architecture, like nature, should not be used instrumentally. Not surprisingly, most of Frei Otto's structures served as pavilions or other structures with limited or vague functions.

Nevertheless, the comparison between natural and human structures is, in the end, still made in the service of the development of human technology: 'Although the history of evolution of living nature is unimaginably old, one cannot prove that the living constructions that exist after so much development are the best.' They concede that it is possible that 'humans will advance technical construction farther... than living nature'.²³ At this point Otto and Helmcke are still focussed on a more instrumental use of nature as the basis for human progress, a goal that would fade over the next decades.

II

These observations on the similarities between natural and artificial constructions hinted at a deeper common origin for them, but it was not

until the 1970s that an attempt was made to encompass all forms, including architectural ones, into a total system. Otto developed a 'standard' of comparison in the form of an invented variable that he called the '*Bic*'.²⁴ The *Bic* value was derived from the interrelationship between three elements in a structure: form, force and mass.²⁵ This was Otto's attempt to translate his theory of lightweight construction into a quantifiable value that could be tested, compared and calculated, allowing for an assessment of the efficiency of a structure. This standard served mainly to 'compare objects of a same form and material, but of differing sizes, or objects of differing form and differing materials, but of the same relative slenderness'.²⁶ The equation used was an ordering framework that allowed for comparisons between what were often wildly heterogeneous objects.

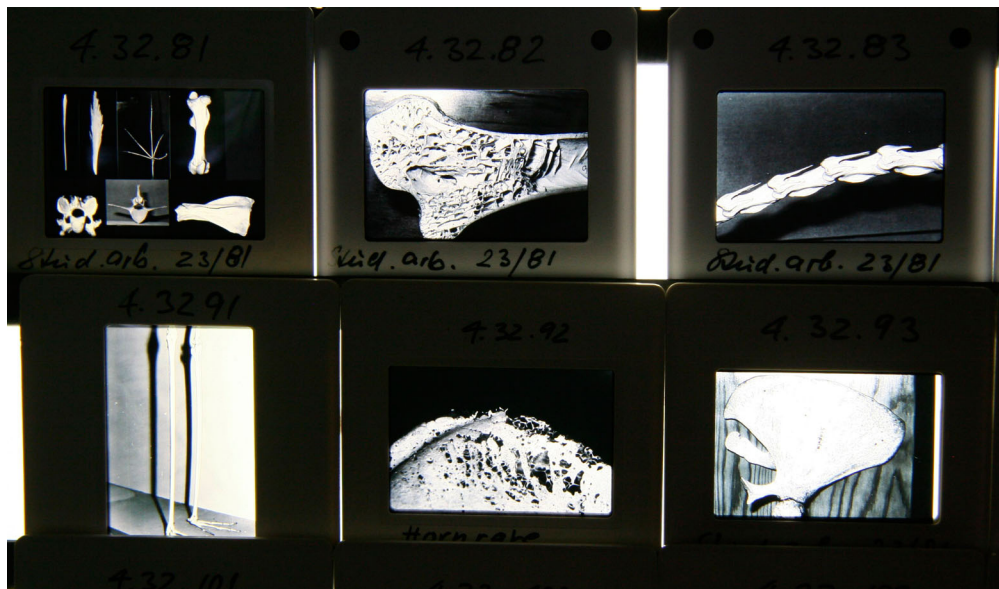
The concept of the *Bic*, which was intimately related to Otto's theories on nature, would become a universal standard of measurement with which Otto classified all natural and artificial structures, including atoms, molecules, ball bearings, tree trunks, branches, grasses, bones, sails, threads, weavings, nets, beams, steel and wood beams, arched and suspension bridges, air halls, tents, space frames, concrete slabs and natural stone, stone churches and towers. These are notably selected from a wide span of moments in the history of evolution. For a publication showing the experimental determination of 'the most important *Bics*' (1979), a variety of materials were loaded to their breaking point: panes of glass, wooden sticks, straw stalks, metal chains, a chicken bone, horse hair, nylon thread, egg shells, sea shells, and

concrete blocks (figs 6, 7).²⁷ Unconventional, natural and everyday materials with potentially extraordinary structural performance appear alongside familiar building materials. The results of these experiments were graphed onto an almost indecipherable chart that encompassed the vast cosmos of objects described. The differing scales of these objects, which could include atoms, crystals, blades of grass, sea shells or planets, required the use of a logarithmic scale so that they could fit into the same space of measurement.

Whilst this taxonomy did not yet suggest a notion of prehistory, it reshuffled the comparison of organic and inorganic life according to a new set of criteria, opening up potential new narratives. It also established a continuity between human and non-human objects, proposing an alternate set of typological categories for architecture.

A more cosmological approach, and one that hinted at an alternative narrative of natural and human history, was the related concept of the '*Pneu*' developed by Otto together with Helmcke. The idea of a lightweight structural membrane filled with air or fluid had fascinated Otto in his early studies of soap films; for Helmcke, the concept of the *pneu* emerged in his research on diatoms, which he believed to have begun as tiny, soft membranes before hardening into filigreed silica structures. In his 1962 book *Zugbeanspruchte Konstruktionen (Tensile Structures)* Otto had already suggested an association between pneumatic structures and plant and animal forms: fruit, air bubbles, blood vessels and skin are cited.²⁸ Pneumatic structures, according to Otto, 'are meeting the justified and growing demand that technology

Figure 6. Photographs from the IL archive showing cross-sections of bones; 1970s–1980s (ILEK Archive).



abandon its abstract, anorganic-mathematical conception, though not its scientific basis, in favour of a conception nearer to organic life'.²⁹

Otto viewed the *pneuma* as a universal concept of enclosure found in all nature, including the human body. He believed that the *pneu* was tied to the origins of life — 'Am Anfang war der Pneu' ('in the beginning was the pneu') he wrote, and it was 'the essential basis of the world of forms of living nature'.³⁰ Otto's interest in the *pneu* was not based on its morphology but quite simply on the way in which it resisted forces and stresses: *pneus* represented some of the lightest forms in nature, and were also con-

sidered the most optimised. This 'great discovery', according to Otto, apparently found few enthusiasts in engineering or in science.³¹ Nevertheless, a conference (the first of many) was organised on the subject at the IL in 1973, and there, according to Otto, 'on Saturday, February 24, 1973, at about 11 a.m. the term *pneu* was coined and its status as origin of all living forms confirmed' (Fig. 8).³²

In order to demonstrate his theory of the *pneu* Otto's research team engaged in a few playful form-finding experiments with threads, fabric, foam and balloons. Even more significant were the photographs of living and dead animals taken

by the IL team members at places such as zoos and slaughterhouses, or those acquired from popular science publications. Because the *pneu* in nature needed no model, so to speak, the photograph became the vehicle through which the natural and the architectural could be placed within the same conceptual system. Images 'from nature and technics' collected under the title of '*pneu*' were extensive and heterogeneous. In addition to foam, bubbles and pneumatic architecture there are 'found' structures such as sails, rubber tubes, upholstery cushions and fishing nets, and also pig intestines, microscopic images of pollen, corn cobs, frog spawn, vegetables, cells, car tyres, amoeba, a human egg ('a few instances before fertilisation'), dividing salamander eggs, clouds, algae colonies, sea-horse skin, human skin, a cow's heart, a Venus fly-trap, multiple exposures of a human penis becoming erect, a section through the finger of a human foetus, a pig's bladder, 'the testicles of a 20-year-old man', an apple next to an image of a girl's navel, a slug, a human brain and skull, and a naked pregnant woman with two children (figs 9, 10).³³

The theory of this universal membrane was so expansive and boundless that it was able to contain these images of seemingly unrelated objects; in fact, it relied on them as evidence. The hope was to universalize the *pneu* theory, producing an alternative encyclopaedia of possible forms and structures that provoke and question the boundaries of what is permissible within architecture. The great amount of material gathered seemed to have no limits, and, as a result, the definition of '*pneu*' seemed just as boundless.



Figure 7. Photograph from the IL archive showing a compressive strength test of an animal bone; 1970s–1980s (ILEK Archive).

This collection of images suggests a continuity between the natural and human worlds in which the human being is treated as merely one 'structural' object among many: a kind of trans-species or trans-materialist manner of thinking. At the same time the special interest in the anatomy of human reproduction hints at the idea that the human is somehow privileged in this collection. Whilst the technological objects created by humans still fall far from the structural optimisation

Figure 8. Conference
on *Pneus* at the IL,
1973.



of a future architecture, the human body by contrast seems to contain potential structures. It is as if the origins of the human body itself—as represented by eggs, sperm, the uterus, the penis, the foetus—offers a kind of new beginning for architecture.³⁴

Otto's *pneu* theory also indicates a kind of 'systems paranoia' typical of a larger cultural condition characteristic of the 1960s, in which systems, data and structures (whether those of the natural or political world) appeared to take on a universal, connected and ubiquitous quality. Here he

describes a 'paranoid' vision experienced by his research team, in which *pneus* seem to appear *everywhere*:

The more that they penetrated the form-world of the *pneus*, and the more they learned to identify *pneus* just from the form, the more *pneus* they saw in biological objects, and they convinced themselves that they truly had real *pneus* before them.... When they then began to catalogue the technical *pneus* and also the biological *pneus*, it seemed almost uncanny to them. They kept seeing more *pneu*-forms in their daily

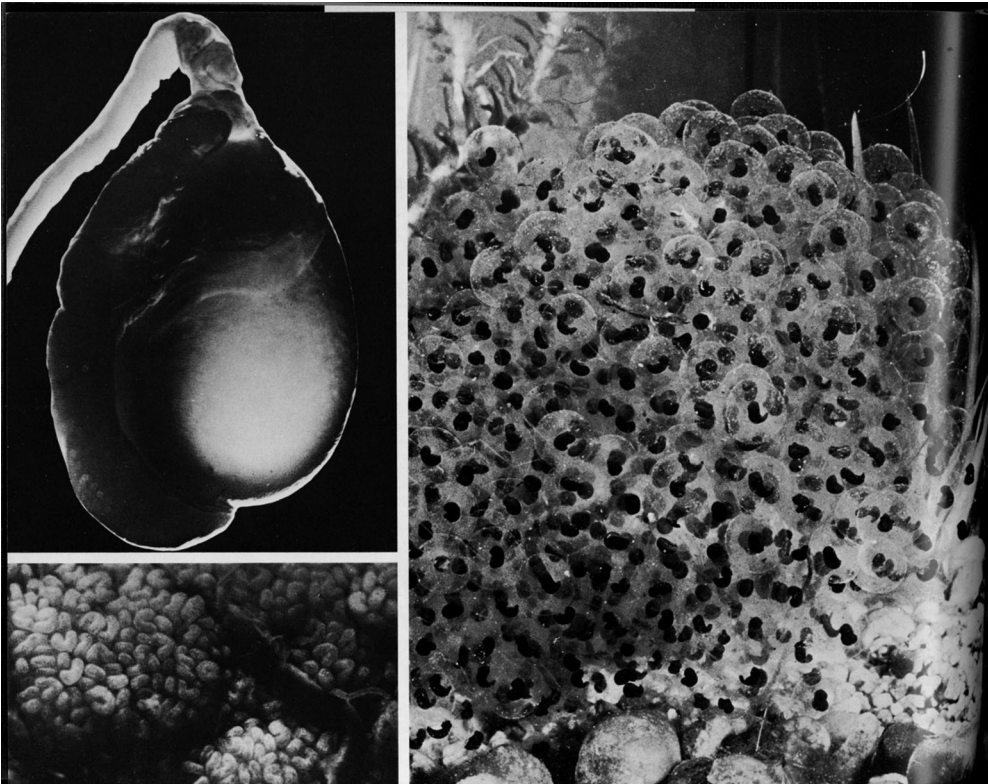


Figure 9. 'Pneus within pneus'; 'Testicles of a 20-year-old man'; 'Inside of testicles with canaliculi'; 'Frog spawn': IL 9: *Pneus in Nature and Technics* (1977).

environment, even in objects that are not even pneus: birds' eggs, apples, insect carcasses, and eventually even in trees and bones. ... The architects of the IL were now seized by something similar to a 'hunting fever'.³⁵

The theory of the *pneu* was eventually met with scepticism by Helmcke. In a letter to Otto (1973) he describes looking through piles of books to find

better evidence of the *pneu*, only to end up with reservations about an idea that he had once enthusiastically endorsed.³⁶ His hesitation centered around the vague definition of the *pneu*, and especially the question of whether objects of such varying scales could really be encompassed by one theory. Nevertheless, conferences, publications and research groups continued to be organised

Figure 10. IL 9: *Pneus in Nature and Technics* (1977).



3. Mensch
Der Mensch ist das am meisten beobachtete und in Bildern dokumentierte Wesen. Er kann sich aber nicht völlig objektiv betrachten. Seine Betrachtungsweise ist anlagebedingt, ästhetisch, sexuell, tabuisiert, medizinisch, anthropologisch (siehe hierzu: Tabu, S. 18.) Für Entstehung und Gestalt des Menschen gilt in besonderer Weise: Der Pneu ist die wesentliche Grundlage der Form Mensch, insbesondere da durch seine Nacktheit die ihn umgebende weiche zugestete Haut ein alle anderen Pneus umschließender Großpneu ist. Um alle anderen Pneus umschließender Großpneu ist. Um alle anderen Pneufomen des menschlichen Körpers vom Großpneu bis zu den Elementen seiner Zellen aufzuzeigen, dürfte ein tausendseitiger Bildband nicht reichen.
Abbildungen auf Seite 302:
> 1 - Schwangere mit Kindern (F: J.F. Bauret; Foto Magazin 7/1970, S.28)
> 2 - Röntgenaufnahme eines Fingers (F: R. Graefe/IL)
> 3 - Embryo, 3 Monate alt (F: Nilsson; op.cit.S.54)
Abbildung auf Seite 303:
> 4 - Nubamann vor seinem Dorf (F: Riefenstahl; Die Nuba von Kau, Munich 1976)

3. Man
Man is the most widely observed living being for whom we have the most abundant picture documentation. Nevertheless, he cannot get an entirely objective assessment of himself. His mode of consideration is determined by hereditary, aesthetic, sexual, tabooed and anthropological factors and influences (see also taboo p. 18). The following especially applies to the origin and form of humans: the pneu is the essential basis of the human form, especially for the reason that because of its nakedness the soft tension-resistant skin surrounding man is a large pneu enclosing all the other pneus. To show all the pneu forms of the human body beginning with the large pneu and ending with the elements of its cells, a 1000-page volume containing illustrations would not be sufficient.
Illustrations on p. 302:
> 1 - pregnant woman with children (F: J.F. Bauret; Foto Magazin 7/1970, p.28).
> 2 - X-ray photograph of finger (F: Graefe, IL)
> 3 - embryo in the 10th week (F: Nilsson; op.cit., p. 54).
Illustration on p. 303:
> 4 - man of the Nuba tribe in front of his village (F: Riefenstahl; Die Nuba von Kau, Munich 1976).



around the topic of the 'pneu' for over a decade at the IL.

III

Falling into neither the typical narratives of architectural history, nor the periodisation of the natural sciences, the theory of the *pneu* was both a structural *and* biological approach to the history of

form. This would lead Otto and Helmcke to a 'deep' concept of history made of up a relatively slow and universal geological time on the one hand, and rapid physical and chemical transformations on the other. This proposes a model of evolution and development in which multiple temporalities overlap and coexist through processes of feedback, mutation and genetic inheritance. The

pneu theory thus tried to span the gap between what Helmcke described as the different temporal modes of the engineer and the biologist. According to Helmcke, 'the biologist tries to understand the form of the present out of the past, while the engineer plans into the future with the possibilities available in the present'.³⁷ In other words, the biologist thinks in terms of processes that take millions of years, while architects and engineers must work under the pressure of a limited amount of time and resources, projecting into the future without thinking of the past.

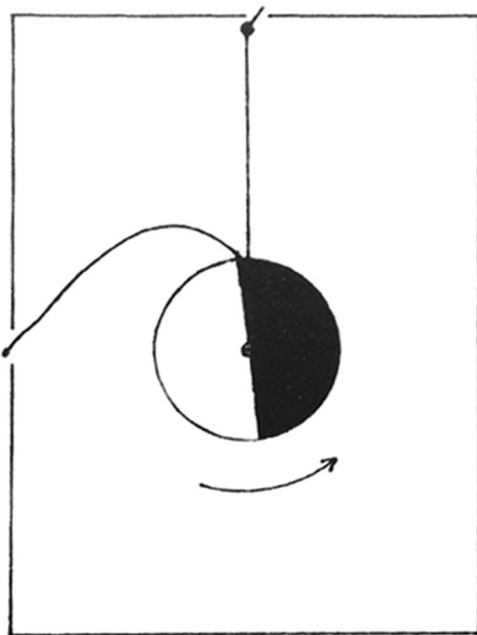
Otto and Helmcke saw an analogous example in nature: there is the long history of a form determined by evolution and genetics, but at the same time, there is the quick formation of structures like diatoms, which they call the 'rapid physio-technical, form-creating processes which take place automatically'.³⁸ Otto referred to this process as 'architectonic'.³⁹ Part of the appeal of this theory for Otto was the hope that structures could form 'of themselves': there need not be a human author. He idealised self-formed structures as born from the intelligence (and what he assumed to be the goodness) of nature, as opposed to the limited capacity, and potential brutality, of the human imagination.

What becomes increasingly clear in these speculations is that human beings are not entirely central to the history, or future, of form and structure. Thus this account differs from the more anthropocentric concepts of today's Deep History, which looks at a period before written history, but is still limited to the history of the (anatomically modern) human species. For Otto and Helmcke, the human is treated as a ready-made object amongst other

animals. Human beings, and animals, were seen not only as makers of structures, but also as structural forms *in themselves*. The structural properties of bones, teeth, hair, skin, bladders and intestines were closely examined at the IL, and in some cases even tested. The human body was viewed as merely one of many living structures, and its own systems, whether skeletal or reproductive, were analysed in isolation under the cool gaze of the engineer. Inversely, non-human objects were seen as capable of writing their own histories: according to Otto 'evolutionary processes stamp their mark on the form of the object. Each individual object, regardless of which area of nature it originates from, tells the history of its evolution, an often fascinating history, and the whole that is formed from them tells much more'.⁴⁰ When architecture is considered in such an expanded manner even its history is no longer limited to the work of human beings.

During the course of the 1970s and 1980s Otto and Helmcke became increasingly concerned with the impact of humans on the natural world and climate, and their arguments for natural structures were now made in favour of global environmental concerns. Otto had observed the deleterious effect of humans on the built environment as early as the 1950s. In an article 'The City of Tomorrow and the Single-Family House' (1956) Otto wrote of the disconnection of humans from 'the weather' through their construction of artificial climates in homes and offices: 'The human rules the earth and changes it. His influence on the *weather* is great, yet he seldom improves it. The creation of climates favourable for life is however the main task of every designer of the environment'.⁴¹ By 1980 Otto viewed humans

Figure 11. 'Catastrophe Machine': IL 27: *Natural Building* (1980).



events that could occur if the forces of man and nature continued to create disequilibrium. He even illustrated his point with a diagram of a catastrophe machine by the mathematician Christopher Zeeman, showing the effect of the push and pull of forces of man and nature (Fig. 11).⁴⁴ According to his description, the 'tension' caused by the forces of man on nature could reach a critical situation in which there is a sudden, catastrophic reversal. Thus, where for Otto and Helmcke natural history had once served as a potential source of inspiration for 'an unimaginable number of different futures', now the focus was on an origin that might be irreversibly lost. The optimism around technology of the early 1960s was replaced by a sense of an incompatibility between natural history and human history. Helmcke wrote: 'If we want to comprehend the concept "nature" in as pure a way as possible, we must refer back to that prehistoric period when there were as yet no people to intervene in the natural equilibrium.'⁴⁵

as not only changing the weather but the entire cosmos of surrounding objects: 'Man has ... been a stranger to the rest of natureHe alienates it, he makes his own world. He is the newcomer. He changes the objects of inanimate and animate nature. He changes himselfHe is ... unnatural towards that wholeness that was here before him.'⁴² This alien behaviour puts man himself at risk: 'Can man really understand nature enough so that he can act naturally? I think that if he cannot do this, his existence is endangered.'⁴³

Around this time Helmcke wrote in even more alarmist tones, warning of irreversible catastrophic

IV

The search for the origins of architecture has been a source of speculation and fascination since architectural history was first written. It also often came as a response to a crisis in the present. In the 1960s, it was the crisis of the broken promises of the Modern movement, and a growing sense of the precariousness of life on earth. Critics of today's discourse of the Anthropocene have argued that the term itself is inherently anthropocentric; that it seeks (human) technological responses to ecological changes, rather than fundamentally questioning human domination over nature.⁴⁶ Otto and

Helmcke, by contrast, challenged anthropocentric thought by de-centering human life and its technologies, and blurring the divisions between animate and inanimate life. In basing a potential future architecture in prehistory—a pre-human history of the earth and cosmos—they hoped to achieve the wholeness and equilibrium that they perceived to have been lost.

I would like to end on a cautionary note, however. Otto and Helmcke's gaze into an architectural prehistory was, paradoxically, only possible through the tools of advanced human technology. Whilst Otto elsewhere opposed the forms of advanced technology and scientific reason that had come to characterise post-war West German society, his ambitious project for finding a universal model for all structures by uniting heterogeneous material and natural histories was very much a product of that society.⁴⁷ Today's search for a universal narrative of human life, or 'species thinking', is similarly made in response to an environmental crisis, but it may also be limited by its positivist tendencies. Just as Otto and Helmcke turned to the human body, rather than human architecture, as a potential source for the origins of a (new) architecture, Deep Historians treat the materiality of the human body as an index of human history. One of the claims made by Deep History theorists is that this is more 'objective', and could potentially liberate history from the bias of authorship. This approach perhaps avoids the problem of the fallibility of human narrative, but raises new problems of agency associated with those non-textual sources (such as: Who has access to carbon-dating technology and genetic databases?). Even if the human body is the potential

material for a universal human history, who will be able to read it?

One could similarly ask if 'species thinking' and other historical models that are centered on animal, material and object evidence are eliminating not only human agency but also human accountability. The human, for Helmcke and Otto, was torn between the animal and technological world, a contradiction that they did not resolve in their own research. Their hope had been to replace the will exerted by human beings' 'outsized hand' with natural and material forces from the scale of the microscopic to the cosmic. This research was driven by a utopian belief that if these forces could be harnessed, they could self-organise to produce a lightness that would counter the heaviness of late-industrial society. The appeal of Otto's research is that it allows for a fascinating glimpse at what a non-human architectural agency might look like. However, the very concept of the Anthropocene is defined by the ecological and geological impact that human will has had on the planet. Reimagining human beings as a species at the receiving end of those acts, as universal biological subjects, could obscure the particular histories of human will that have threatened our existence.

Notes and references

1. Published in Universität Stuttgart. Institut für Leichte Flächentragwerke, *IL 9: Pneus in Nature and Technics*, Information of the Institute for Lightweight Structures (Stuttgart, 1977).
2. *Ibid.*
3. Universität Stuttgart. Institut für Leichte Flächentragwerke, *IL 27: Natural Building*, Information of the Institute for Lightweight Structures (Stuttgart, 1981), p. 21.
4. *Ibid.*, p. 25.

5. Robert Smithson, 'Ultramoderne', in, Robert Smithson, *Robert Smithson: the Collected Writings* (Berkeley, University of California Press, 1996), pp. 62–65; 63.
 6. On Kubler and Smithson, see, Pamela M. Lee, "'Ultramoderne": Or, How George Kubler Stole the Time in Sixties Art', *Grey Room*, No. 2 (Winter, 2001), pp. 46–77; on Giedion's prehistory, see, Spyros Papapetros, 'Beginnings or Origins—Beginnings and Endings: Sigfried Giedion's (Pre)Historiography', *Journal of Architectural Education*, Vol. 65, Issue 2 (March, 2012), pp. 9–12.
 7. See, Hal Foster, 'The "Primitive" Unconscious of Modern Art', *October*, Vol. 34 (Autumn, 1985), pp. 45–70.
 8. Alan Weisman, *The World Without Us* (New York, Thomas Dunne Books/St. Martin's Press, 2007).
 9. See, Daniel Lord Smail, *On Deep History and the Brain* (Berkeley, CA, University of California Press, 2008); Andrew Shryock, Daniel Lord Smail, *Deep History: The Architecture of Past and Present* (Berkeley, CA, University of California Press, 2012)
 10. Humans have become geological agents very recently in human history. In that sense, we can say that it is only very recently that the distinction between human and natural histories—much of which had been preserved even in environmental histories that saw the two entities in interaction—has begun to collapse. For it is no longer a question simply of man having an interactive relation with nature. This humans have always had, or at least that is how man has been imagined in a large part of what is generally called the Western tradition. Now it is being claimed that humans are a force of nature in the geological sense. A fundamental assumption of Western (and now universal) political thought has come undone in this crisis.
 11. *Ibid.*, p. 221.
 12. Bruno Latour, *We Have Never Been Modern* (Cambridge, Mass., Harvard University Press, 1993).
 13. F. Otto, *Das hängende Dach. Gestalt und Struktur* (Berlin, Bauwelt Verlag, 1954), p. 158. [My translation.]
 14. Frei Otto, 'Mit Leichtigkeit Gegen Brutalität', in *Schriften und Reden 1953–1983*, Berthold Burkhardt, ed. (Braunschweig, Vieweg, 1984), pp. 128–132.
 15. J.-G. Helmcke, W. Krieger, *Diatomeenschalen im elektronenmikroskopischen Bild*, vol. 1 (Weinheim, J. Cramer, 1962), p. 3. [My translation.] Helmcke even included a pair of stereoscopic glasses with the original edition of the book.
 16. The group was known as 'TUB-TUB' (Technik und Biologie an der Technischen Universität Berlin). Details of group can be found in the essay 'Die Forschungsgruppe Biologie und Bauen', in, Frei Otto, *Schriften und Reden 1951–1983*, *op. cit.*, pp. 170–173. Further information can be found in, Frei Otto, 'Beitrag zum Internationalen Symposium des SFB 64 "Weitspannende Flächenstragwerke" in Stuttgart. Konzept für den Vortrag J.-G. Helmcke. Thema: Das SFB und die Biologie' (Manuscript, April, 1976; Helmcke Archive, Staatsbibliothek Berlin).
 17. Heinrich Hertel, *Struktur, Form, und Bewegung* (Mainz, Krausskopf Verlag, 1963).
 18. Konrad Wachsmann, *Wendepunkt im Bauen* (Wiesbaden, Krausskopf Verlag, 1959); English translation: *The Turning Point of Building: Structure and Design* (New York, Reinhold, 1961).
 19. Letter from Helmcke to Otto, 12th July, 1973 (Helmcke Archive, Staatsbibliothek Berlin).
 20. Universität Stuttgart. Institut für Leichte Flächentragwerke, *IL 38: Shells in Nature and Technics III*; Information of the Institute for Lightweight Structures (Stuttgart, 2004), p. 141. Otto describes a similar visit to Berlin by Buckminster Fuller, during which Helmcke showed him stereoscopic images of diatoms
- Dipesh Chakrabarty, 'The Climate of History: Four Theses', *Critical Inquiry*, 35 (Winter, 2009), pp. 197–222; 207.

that resembled his domes. When he saw them, Fuller 'stood up and wanted to reach into the stereoscopic images; 'Die Forschungsgruppe Biologie und Bauen', p. 171.

21. J.-G. Helmcke, Frei Otto, 'Lebende und Technische Konstruktionen: Bemerkungen zu Schalen und Raumtragwerken in Natur und Technik', *Deutsche Bauzeitung*, 11 (1962), pp. 856–861; 856. [My translation.]
22. *Ibid.*, p. 858.
23. *Ibid.*
24. According to Otto the name 'Bic' was coined in 1965 at the IL, and derived by randomly selecting combinations of *Scrabble* letters: Universität Stuttgart. Institut für Leichte Flächentragwerke, *IL 24: Form Force Mass 4—The Lightweight Principle*, Information of the Institute for Lightweight Structures (Stuttgart, 1998). Out of fifteen possibilities, 'Bic' was chosen because it sounded like the name of Otto's beloved structures teacher at the TU Berlin, Helmuth Bickenbach.
25. In other versions it is form, force, path and mass; Universität Stuttgart. Institut für Leichte Flächentragwerke, *IL 21: Form Force Mass 1—Basics*, Information of the Institute for Lightweight Structures (Stuttgart, 1979), p. 42.
26. *IL 24*, p. 56.
27. *IL 21*.
28. Frei Otto, *Zugbeanspruchte Konstruktionen* (Frankfurt, Ullstein, 1962).
29. Frei Otto, *Tensile structures; design, structure, and calculation of buildings of cables, nets, and membranes*, 2 vols (Cambridge, Mass., The MIT Press, 1967), p. 10. This is the English translation of *Zugbeanspruchte Konstruktionen*.
30. *IL 9*, p. 5.
31. It is interesting to note to what extent Otto, who had been an early pioneer in pneumatic structures, took this concept in an entirely different direction from the adherents to the pneumatic craze of the counterculture of the 1960s. This split indicates, among other things, Otto's ambivalence toward the architectural neo-avant-garde.
32. *IL 9*, p. 194.
33. *IL 9*.
34. Again, an image from Kubrick's *2001: A Space Odyssey* comes to mind: the foetus of the 'star child', housed in a transparent 'pneu' floating in space towards the planet Earth, where it will have an unknown effect on human evolution.
35. *IL 9*, p. 16. [My translation.]
36. Letter from Helmcke to Frei Otto, 1st February, 1973 (Helmcke Archive, Staatsbibliothek Berlin).
37. J.-G. Helmcke, 'Strukturen der Natur und Konstruktion des Menschen. Der mensch und die Technik', *Süddeutsche Zeitung* (28/05/71).
38. *IL 9*, p. 17.
39. *Ibid.*
40. *IL 27*, p. 19.
41. Frei Otto, 'Die Stadt von Morgen und das Einfamilienhaus', *Baukunst und Werkform*, 12, IX (1956), pp. 642–652; 647. [Emphasis in the original, my translation].
42. *IL 27*, p. 1.
43. *IL 27*, p. 23.
44. J.-G. Helmcke, 'Natural Building: Considerations of Wholeness and the Concept of Nature', *IL 27*, pp. 26–31.
45. *IL 27*, p. 26.
46. Eileen Crist, 'On the Poverty of Our Nomenclature', *Environmental Humanities*, vol. 3 (2013), pp. 129–147.
47. As mentioned in the introduction, Hal Foster has similarly argued that the idealisation of the primitive could only have been made from the position of privilege of Western reason.