Chapter 8
Biomorphism in Architecture: Speculations on Growth and Form

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Abstract Many of the design methods applied by the current architectural avant-garde can be traced back to one of the oldest and most influential ideas in architectural history: the concept of organicism in its various guises. The basic idea of organicism, to take nature as model, is one of the most oldest and most fundamental aesthetic concepts in western art and architecture theory. Since the Renaissance, it has shown an uninterrupted continuity, influencing architecture on both the conceptual and the metaphorical levels. Not only classical but also modern architects attempted to imitate natural forms or processes in design. While the influence of classical philosophers waned during and after the Enlightenment, the appeals to the authority of nature only intensified. Thus, the study of organicism concerns a very basic question in the history of architectural theory as well as in the current discourse.

8.1 Introduction

The form, then of any portion of matter, whether it be living or dead, and the changes of form which are appearent in its movements and in its growth, may in all cases alike be described as due to the action of force. In short, the form of an object is a 'diagram of forces', in this sense, at least, that from it we can judge of or deduce the forces that are acting or have acted upon it [1]. The basic idea of biomorphism, bionics, and organicism in architecture, to take nature as model, is one of the most oldest and most fundamental aesthetic concepts in western art and architecture theory. Since the Renaissance, it has shown an uninterrupted continuity, influencing architecture on both the conceptual and the metaphorical level. As late

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as 1747, French philosopher and aesthetic Charles Batteux still reduced the fine arts to a single principle, that of *ars imitatur naturam*.

The Aristotelian theory of organic form, as defined by Friedrich Schlegel and Samuel Taylor Coleridge (and restated by some of the most famous twentieth century architects, Frank Lloyd Wright, Hugo Häring, Le Corbusier, and other architects following functionalist ideas), implies that the *unfolding* of the innermost essence of a being is the source of value, and that any outside influences could only be harmful. Aristotle does not hesitate to reason, for example, that "if the movement of the soul is not of its essence, movement of the soul must be contrary to its nature" [2]. This line of organicism sponsored functionalism and led naturally to an interest in "authorless" planning, biomorphic strategies, vernacular traditions, and user planning, all explored by many architects over the past decades. It also underlies more recent avantgarde concepts such as the "death of the author," which redefine the role of the architect and provide a philosophical foundation for contemporary design methods that use computer-generated forms and design algorithms while referring to natural sciences.

The obvious difficulty in designing from the inside out is to determine what the essential nature of a building is. While Peter Eisenman's early houses or Greg Lynn's projects have occasionally been understood as proposing the building as an end in itself, most architects choose to see a house as a reflection, expression, or extension of its inhabitant. In the *Nicomachean Ethics*, Aristotle maintained that "handicraft is he that made it," implying that the limits of an entity are not the limits of its immediate body but that houses and machines, for example, are parts of living beings, extensions of man [3]. Following this suggestion, a house should be read neither as "dead matter" nor as a natural entity but as a natural secretion of a person in the same sense that a snail secretes its shell.

Not only classical but also modern architects attempted to imitate natural forms or processes in design. Sir James Hall proposed already around 1793 a neogothic willow cathedral constructed of living trees, which was rebuilt for the IGA in Rostock 2003 (Fig. 8.1). While the influence of classical philosophers waned during and after the Enlightenment, the appeals to the authority of nature only intensified. Thus, the study of organicism and bionics in architecture concerns a very basic question in the history of architectural theory as well as in the current discourse.

8.2 The Essence of Nature

Despite a long line of various traditions of *ars imitatur naturam*, nature has not always been considered as a purely positive realm. We do not have to go far in history to find vivid attacks of nature such as postulated by Leopardi:

Now despise yourself,
Nature, you brute force
who furtively ordain universal doom,
and the infinite futility of all existence [4].

Fig. 8.1 James Hall, Willow Cathedral, credit: RIBA Library Drawings Collection

With these terse and chilling words, Giacomo Leopardi ended his poem "To Himself" in early 1833 [4]. Although the poem hit a new lugubrious low in western letters, Leopardi was not proposing anything novel. In his resentment of nature, he was rather perpetuating a tradition which goes back at least to the Orphic doctrine of *soma sema*, according to which the body (and by extension all nature) is a cruel and alien prison from which the human soul struggles to break free to return to its proper spiritual home.

Yet, the overwhelmingly dominant tradition of Western thought is predicated on the confident identification of the natural with the good. Seventy-five years before Leopardi's poem, Denis Diderot stated categorically that "water, air, earth and fire, everything in nature is good. Even the gale, at the end of autumn, which rocks the forests, beats the trees together, and snaps and separates the dead branches; even the tempest, which lashes the waters of the sea and purifies them; even the volcano, casting a flood of blazing lava from its gaping side, and throwing high into the air the cleansing vapour." Rejecting anthropocentric ethics, Diderot defined the good as that which comes from nature as opposed to anything devised by man who has been "perverted by the wretched customs of society" [5].

The inherent goodness of nature has been accepted by most classical thinkers who have sought to ground both ethics and aesthetics on the example of nature. Aristotle's definition of art as the imitation of nature provided the unquestionable premise for two millennia of classicism.

Looking at the most recent developments in architecture, there are certainly different ways the Aristotelian principle of *ars imitatur naturam* has been applied, both in architectural theory and in design. Besides the Platonic, imitation of the forms of natural beings, many architects picked up issues of anthropomorphic

proportion, the doctrine of form and function being interdependent, the implications of ecological thinking for architectural theory, the influence of natural sciences, and, finally, the very concept of organic unity.

8.3 Nature as a Source for Form

Like the current avantgarde, architects of the past turned to contemporary debates in philosophy and natural sciences to develop new design strategies. In architecture, the notions of organicism led to the rather Platonic imitation of natural forms (Mimetics). Callimachus, the alleged inventor of the Corinthian order, is credited for designing a bronze chimney in the form of a palm tree in the Erechtheion. The application of plant and animal shapes to ornaments constitutes perhaps the most obvious case of architecture imitating nature, but the principle was not always limited to small details. Claude-Nicholas Ledoux designed a phallic-shaped brothel (1792) and Lequeu a dairy in the form of a cow (1790). Later, Rudolf Steiner married Callimachus and Ledoux in his design for the heating plant in Dornach (1914); Herb Greene built his vacation house in a shape evocative of a buffalo or a "prairie chicken," (1960) and Imre Makovecz gave the dormers in his buildings eyelashes (1982).

Even though modern functionalist architects rejected naturalist ornaments, they still found in nature "the eternal example for every human creation," to quote Walter Gropius. Not only for Frank Lloyd Wright but also for his arch-enemy Le Corbusier, Mother Nature was the "great and eternal teacher" [6]. Yet the lessons they learned from their eternal *alma mater* were radically different. Even poststructurally oriented theorists, such as Greg Lynn and Daniel Libeskind, often make references to nature and to the natural sciences, although their work can be seen as a re-interpretation if not a challenge of the organic paradigm.

In most cases, such a design approach was based more on semiotic than aesthetic concerns. The champions of *l'architecture parlante*, for example, reached for a universally understandable language of architecture. Makovecz, on the other hand, has attempted to get to the essence of architecture by investigating the biomorphic etymologies of Hungarian words related to buildings. Other architects have sometimes adopted natural forms for structural purposes. Henrik Petrus Berlage, inspired by one plate of Ernst Häckel's popular *Art Forms in Nature*, used one of his jelly fish images to design a lamp (Fig. 8.2).

However, the more recent designs of Frank Gehry, Future Systems, Renzo Piano, and others also show strong affinities to the structures of natural organisms. Santiago Calatrava and Nicholas Grimshaw, for instance, design expressive skeletons that fold and bend like body parts, as can be seen in Calatrava's garage door that folds like an eyelid. Even more explicit may be the shape of the H_2O Pavillon by Nox and Oosterhuis architects, which evokes a stranded whale while its interior

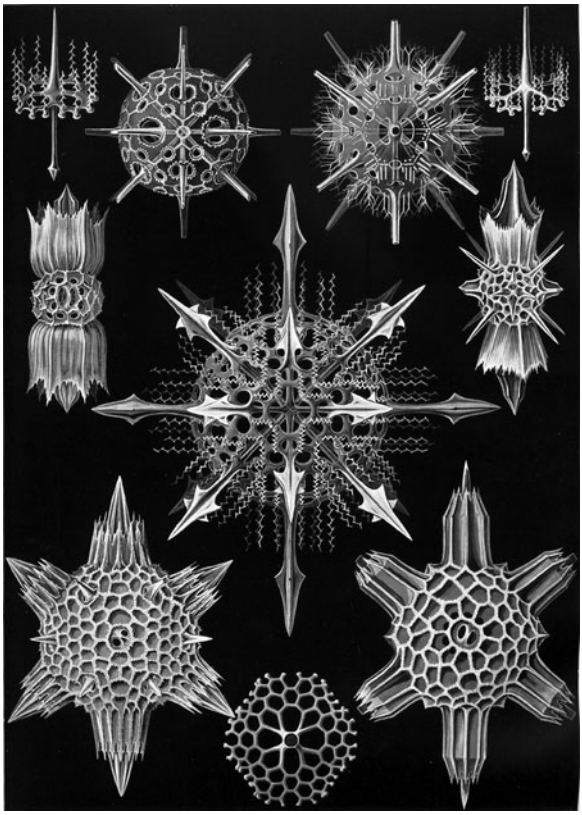

Fig. 8.2 Ernst Haeckel, Acanthrophracta- Tafel aus Kunstformen der Natur

seems to address the fluidity of a virtual, liquid "Deleuzian" space.[1] The computer-generated designs of Greg Lynn, Lars Spuybroek, and Jeff Kipnis follow a "blob grammar," which resembles the amorphous forms and viscous transformations of natural organisms one sees in floating jellyfish [7].

8.4 Natural Processes

In his Hydrogen House project for Vienna, Greg Lynn for example started with a simple, symmetrical triangular volume which gets deformed in a process by solar rays and the shadows they cast on the building. Lynn calculated each phase of the transformational process with a computer and simulated the changing shape

[1] Deleuze considers traditional notions of space and time as unifying forms imposed by the subject. He claims that pure difference is non-spatio-temporal, an idea, which he calls "the virtual".

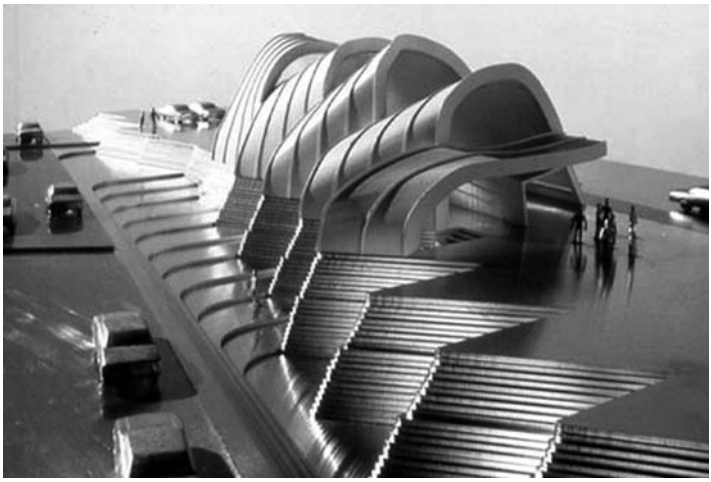

Fig. 8.3 Greg Lynn, Hydrogen House Vienna, credit: © Greg Lynn

of the building (Fig. 8.3). The result is a metamorphosis of form as a movement in time proceeding from east to west. In this regard, the Hydrogen House no longer confesses to "the ethics of stasis". Lynn explains: "Architectural form is conventionally conceived in a dimensional space of idealized stasis, defined by Cartesian fixed-point coordinates. An object defined as a vector whose trajectory is relative to other objects, forces, fields and flows, defines form within an active space of force and motion. This shift from a passive space of static coordinates to an active space of interactions implies a move from autonomous purity to contextual specificity" [8].

For the Hydrogen House and other designs, Lynn has produced computer videos that explain the generation of the forms from the dynamic interaction of contextual forces. The animated sequence illustrates the dynamism vividly, but at some point, Lynn always stops the process and chooses a static image as the finished design for the building is not itself supposed to move. Many critics have complained about Lynn fetishizing the dynamic animation video but then taking the motion away from the actual architectural object. Yet it is possible that the Hydrogen House is not the best illustration of animate form: because the work was for a while intended to be built, Lynn might have had to make compromises concerning construction, cost, or other factors. His Long Island House Project, on the other hand, must be taken as representative of his main interests, as no external matters enter into the design process. It is remarkable how closely the project resembles late sculptures by Umberto Boccioni.[2]

[2]The design began as an analyses for a small weekend house. Lynn mapped the site based on visual attractors using forces of various shapes. Into this field of forces he placed various flexible house prototypes in order to study their alignments and deformations.

Some of Lynn's designs end up much the same way as Boccioni's sculpture: as symbolic depictions of movement or dynamic forces. The objects simply are not animate, unless the word "animate" is understood in a special sense. Indeed, Lynn articulated this sense in explaining that "animation is a term that differs from, but is often confused with, motion. While motion implies movement and action, animation implies the evolution of a form and its shaping forces; it suggests animalism, animism, growth, actuation, vitality and virtuality" [9]. While Lynn's characterization of "animation" (which is probably meant to apply to "animate" as well) differs from those in standard dictionaries, it is nonetheless enlightening. Most of the words in the above quote are recognizable as shorthand for ideas that Lynn discussed in his earlier essays: "actuation" and "virtuality" referred to Deleuze's philosophy, "growth" perhaps to D'Arcy Thompson's *Growth and Form*, and "vitality" probably to Bergson's vitalism [10]. The word "animism" seems to be a recognition of the fact that seeing Lynn's designs as animate require a kind of *Einfühlung* or empathy which is also present in animistic religions. To understand Lynn's reference to "animalism", however, one needs to consider an earlier discussion of animate form: theosophical speculation on "hyperspace", in particular by P. D. Ouspensky and Claude Bragdon.

Long before Lynn, Frei Otto explored different ways of re-interpreting natural systems to develop architectural shapes and structures. Opposed to Lynn, he was interested in the form rather than the process or motion. From the early 1970s, Frei Otto began fusing forms found in nature with modern building techniques and computer logistics. His book *Biology and Building 2* (1972) examined ways in which the lightweight sandwich construction of bird skulls could be applied to architecture; a further volume published the following year dealt with the strength and beauty of spiders' webs. The goal of Otto was to stretch man-made structures to their limits with a most economical use of material. Further research examined the structure and building properties of for instance bamboo and soap bubbles (Fig. 8.4).

Fig. 8.4 Frei Otto, credit: © BauNetz Media, see www.baunetz.de/db/news/?news_id=82689

Otto observed that given a set of fixed points, soap film will spread naturally between them to offer the smallest achievable surface area. Several experiments followed and Otto established his position between architect, artist, and engineer. His quest to discover light, strong, responsive, and elegant structural solutions for buildings drew his research toward nature as reflected in his 1995 study *Pneu and Bone*, which considered the structural properties of crustaceans [11]. Another very promising direction has more recently been taken by Shigeru Ban, who was certainly influenced by Frei Otto, with whom he later also collaborated, by developing architectural shapes in relation to natural bubble and parabolic structures.

8.5 Organic Versus "Mechanical" Form

Organic forms have often been opposed to geometric forms. Peter Sloterdijk's book *Sphären* has been considered by many architects to be a standard reference work of organically shaped and pneumatic architectonics such as presented in the early 1970s by Cedric Price, Coop Himmelb(l)au or Haus-Rucker, to name but a few [14c] (Figs. 8.5 and 8.6). The idea was to create a new kind of living environment which is not only a second skin for its human inhabitants but rather an organically shaped living structure. However, under the influence of aerospace industry, such formal ideas were often connected to utopian visions of a future world with new building materials, future techniques, and of course a different society that was still to come. Reyner Banham critically described these architects as "Zoom Wave Newcomers" who present an alternative architecture – that would be perfectly possible if only the Universe was differently organized [12, 13].

Fig. 8.5 Haus Rucker & Co, credit: © Haus Rucker & Co

Fig. 8.6 Installation von Haus Rucker & Co am Friedericanium in Kassel zur documenta 5, credit: Haus Rucker & Co

Although Frei Ottos experiments had a much more rational starting point, they were still a challenge for the clean cut right angle of modernism (Figs. 8.7 and 8.8). Yet organic and geometrical shapes were not always seen as oppositions. Louis Sullivan, for example, started with a simple square intersected by diagonal and orthogonal axes to create delicately floral motifs. In his "Essay on Inspiration," he describes the fusion of geometric and organic forms as a design principle of nature, finding in it a transcendental, religious dimension. Influenced by Emanuel Swedenborg, a Swedish scientist, philosopher, Christian mystic, and theologian, Sullivan recognizes the "feminine" principle in floral, organic forms which emerge from the underlying geometric "masculine" form. The idea that life is generated from such oppositions and that the universe rests on a dualist foundation is a fundamental idea in his architecture [14].

Interestingly enough, Sullivan saw no contradiction between ornament and function, despite his reputation as a forerunner of modernist theory; rather, he considered ornament as a necessary element. The opposition of geometric versus amorphous forms, which was not an issue for Sullivan, bitterly divided later theorists. One problem concerned the definition of organic form. Claude Bragdon saw two fundamental possibilities, designed vs. organic architecture, and recognized this duality as a basic principle of life. Designed architecture is conceptual and

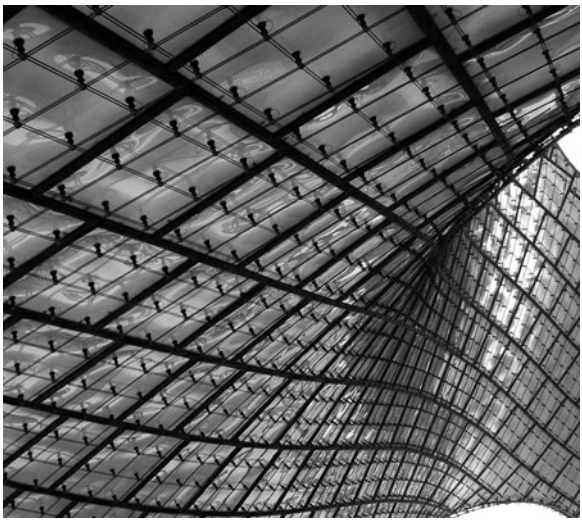

Fig. 8.7 Frei Otto, Olympic Stadion, Bilderarchiv Institut für Architekturwissenschaften, TU Wien

Fig. 8.8 Frei Otto, Olympic Stadion, Bilderarchiv Institut für Architekturwissenschaften, TU Wien

artificial, created by talent and influenced by taste, whereas organic architecture is unconscious, free, and imaginative. However, he had to concede that the two kinds of architecture could not always be clearly separated [15]. In a similar vein, Walter Curt Behrendt talked in the 1930s about the opposition between organic and mechanical order [16].

Numerous attempts to limit organic theory to the formal phenomenon alone could not survive closer scrutiny and in practice led to an incoherent set of divergent variations. Antoni Gaudi's or Hermann Finsterlin's positions, for example, were criticized by Bruno Zevi who felt that organic architecture should never be understood as the application of forms derived from or inspired by plants and animals nor as the more metaphorical representation of nature. Again and again in his *Towards an Organic Architecture*, he disavows the use of biomorphic imagery which in his mind reduces aesthetic pleasure to physiological or sexual sensations [17].

A new solution to the age-old dilemma of organic vs. mechanical form was offered in the 1970s by the popularization of fractal geometry. This branch of mathematics was popularized by Benoit Mandelbrot, who promoted it as a geometry of nature. Frustrated with the inadequacy of mathematics to model certain natural phenomena, Mandelbrot found that the apparent disorder of nature reveals, on closer inspection, repetitions of certain structures [18]. He was able to provide equations that reproduced the irregular, fragmented patterns of natural phenomena, through the use of iterative processes: branches of trees made from innumerable smaller branchlets, a convoluted coastal landscape comprised of countless smaller involutions, the shape of a feather created out of myriad smaller "feathers" at ever smaller scales. Mandelbrot traces this observation back to Eugene Delacroix who in his turn refers to Swedenborg's claim "that the lungs are composed of a number of little lungs, the liver of little livers, the spleen of little spleens" and so forth [19].

8.6 Bionics and Cyborgs

The American author and architecture theorist Anthony Vidler stated in the early 1990s that the boundaries between the organic and the inorganic have been blurred by cybernetic and biotechnologies. Nowadays, they seem to be less sharp than ever before: "the body, itself invaded and re-shaped by technology, invades and permeates the space outside, even as this space takes on dimensions that themselves confuse the inner and the outer, visually, mentally and physically" [20].

Indeed, inspired by countless science fiction novels, recent developments in medicine and virtual intelligence, intelligent materials, automation, etc., the architectural discourse turned once more to the old idea of the house as second skin or living being.[3] However, this time the question was where to draw the line between

[3]This debate originated in Jack E. Steeles work, who coined the term bionics, and his research on cyborgs, which inspired Science Fiction writer and aviation expert Martin Caidin, to write his famous Cyborg book in 1972. The popular American TV series The Six Million Dollar Man (and the following spinoff The Bionic Woman), popularized, unfortunately somewhat inaccurately, the term bionics. Steele's original intention for bionics was the study of biological organisms to find solutions to engineering problems, a field which is today known as biomimetics. The interpretation of the biological paradigm represented by the so-called signs of life was examined in [21].

building and user or the natural and the artificial. Donna Haraway's famous *Cyborg Manifesto* became a strikingly important new philosophy for several architects and theorists which sponsored again an interest in natural processes and the question of what the essence of an organism might be: "A cyborg is a cybernetic organism, a hybrid of machine and organism, a creature of social reality as well as a creature of fiction. Social reality is lived social relations, our most important political construction, a world-changing fiction. The international women's movements have constructed 'women's experience', as well as uncovered or discovered this crucial collective object. This experience is a fiction and fact of the most crucial, political kind. Liberation rests on the construction of the consciousness, the imaginative apprehension, of oppression, and so of possibility. The cyborg is a matter of fiction and lived experience that changes what counts as women's experience in the late twentieth century. This is a struggle over life and death, but the boundary between science fiction and social reality is an optical illusion" [22]. As Haraway pointed out, cyborg refers to cybernetic organism, describing a kind of hybrid of the natural and the artificial, mechanical. Originally, the term "cybernetics" was introduced by the mathematician Norbert Wiener in the 1940s to describe the study of complex systems of control and communications in animals and machines. Hernan Diaz Alonso explored these issues in several formal experiments, which would usually turn into exhibition architecture but sometimes housing projects as well. His designs recall the aesthetics of science fiction artist Giger yet also surpass the borderline between art and architecture, sculpture and building, organism and machine (Figs. 8.9–8.11).

However, soon the debate moved from the individual building to the urban context and contemporary city planning including infrastructure, as Gandy pointed

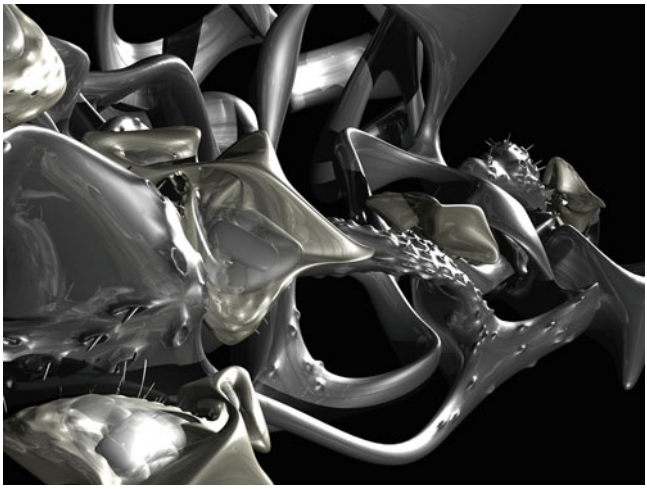

Fig. 8.9 Hernan Diaz Alonso, Prototype Concepts Cell Phone, credit: *Diaz-Alonso Project: Cell* 2006/Cell Phone/Prototype Concepts Client – Confidential © Xefirotarch/MAK

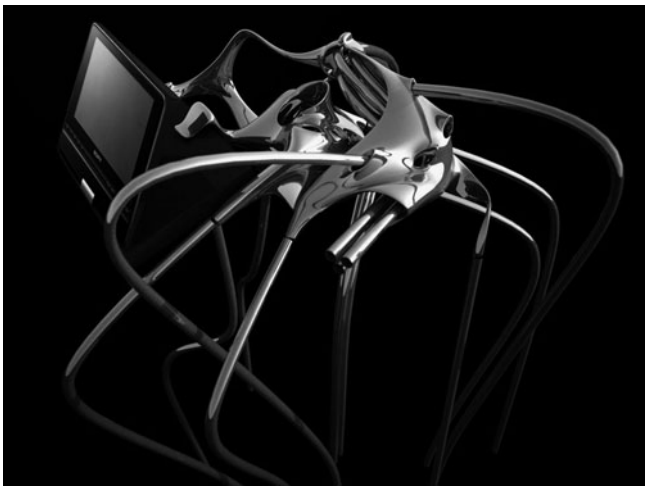

Fig. 8.10 Hernan Diaz Alonso, *Exhbtn Detail Pitch Black, "Spider", credit: Diaz-Alonso PITCH-BLACK, 2007, Rendering, Hernan Diaz Alonso* Detail, Spider © Xefirotarch/MAK

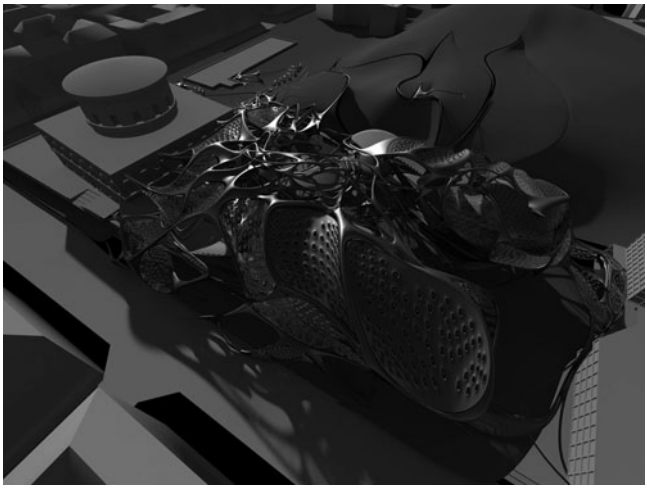

Fig. 8.11 Hernan Diaz Alonso, *Project: Stockholm* 2006, credit: *Diaz-Alonso, Project: Stockholm* 2006/Stockholm/Competition, Stockholm Sweden, © Xefirotarch/MAK

out: "The emphasis of the cyborg on the material interface between the body and the city is perhaps most strikingly manifested in the physical infrastructure that links the human body to vast technological networks. If we understand the cyborg to be a cybernetic creation, a hybrid of machine and organism, then urban infrastructures can be conceptualized as a series of interconnecting life-support systems" [23]. The modern home, for example, has become a complex exoskeleton for the human body with its provision of water, warmth, light, and other essential needs. The home

can be conceived as "prosthesis and prophylactic" in which modernist distinctions between nature and culture, and between the organic and the inorganic, become blurred. And beyond the boundaries of the home itself we find a vast interlinked system of networks, pipes and wires that enable the modern city to function. These interstitial spaces of connectivity within individual buildings extend through urban space to produce a multi-layered structure of extraordinary complexity and utility" [24].

From this perspective, it is only a short move to questions of superorganisms, ecology, and more recently new concepts of sustainability, and the idea, that everything is connected, while a small change in one area might challenge the whole system (as exemplified in the butterfly effect).

8.7 Ecology

A building could be seen as issuing from its inhabitant, but it could also be seen as growing from the earth like a plant, much as national styles and art forms (according to Johann Gottfried Herder) arose from the soil of their time and place. In recent years, ecological architecture has become the focus of much research, provoked by the 1970s energy crises. However, while attempts to develop sustainable architectural systems with minimal energy use and minimal waste are certainly important, the theoretical implications of ecology also need to be addressed. One of the central issues concerns the individuation of organisms in ecological thought. Instead of conceiving of a plant or an animal as a separate entity as would have Carl Linneus, ecologists usually focus on populations and the interrelation of organisms and nonliving nature in ecosystems. A squirrel could in fact not exist without the plants it eats; these would not grow except for certain minerals, water, air, etc. Logically applied, then, the ecological point of view entails the concept of an ecological *superorganism*, a concept proposed by Frederic Clements in 1916. It states that different ecosystems are organisms in their own right, with particular emergent properties that their constituent parts, animals, and plants do not have.

The application of such considerations to architectural and urban design raises several questions. Just as no organism is self-sufficient but rather merely an open system interacting with others in a larger ecosystem, neither are buildings self-sufficient nor independent. In cities, building tap into the infrastructure of water pipes and sewers, electric lines and communications, and streets. This idea was given artistic and graphic expression in Peter Eisenman's *Wexner Center for the Visual Arts* in Cincinnati, where the grid of the building extends onto the sidewalks as inlaid brick in the concrete.

Frei Otto and Shigeru Ban addressed this question of interconnection and interaction of architectural systems and their environment from a global ecological perspective. The main theme of their Japan Pavilion at Hanover Expo was to create a structure that would produce as little industrial waste as possible when it was

Fig. 8.12 Frei Otto, Shigeru Ban, Japanese Pavillon, Expo Hanover, Model, credit: shigeru ban architects

Fig. 8.13 Frei Otto, Shigeru Ban, Japanese Pavillon, Expo Hanover, exterior, credit: shigeru ban architects

dismantled (Figs. 8.12 and 8.13). The goal was either to recycle or to reuse almost all of the materials that went into the building. The structural idea is a grid shell using lengthy paper tubing without joints. The tunnel arch was about 73.8 m long, 25 m wide, and 15.9 m high. The most critical factor was lateral strain along the long side; so instead of a simple arch, a grid shell of three-dimensional curved lines was chosen with indentations in the height and width directions, which are

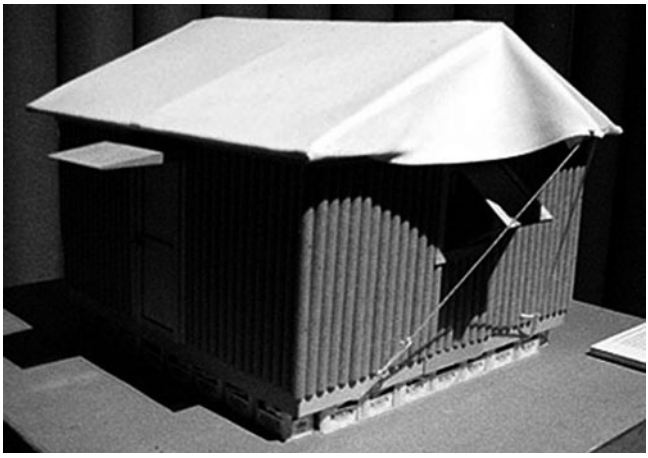

Fig. 8.14 Shigeru Ban, Modell Paper-Log-House, Kobe, credit: shigeru ban architects

stronger when it comes to lateral strain. One has to keep in mind that the artistic agenda behind this project is just as important as in Eisenman's building, the main difference being that Otto and Ban preferred nonstandard, innovative structures and materials, while considering issues of industrial waste.

Shigeru Ban's temporary "log" houses in Kobe, Kaynasli, and Bhuj also explore issues of ecology and sustainability, however, this time built for the victims of the earthquakes in catastrophe areas (Fig. 8.14). The temporary shelters have foundations that consist of donated beer crates loaded with sandbags. The walls are made of 106-mm diameter, 4-mm thick paper tubes, with membrane roofs. For insulation, a waterproof sponge tape backed with adhesive was sandwiched between the paper tubes of the walls. Sustainability does not only concern building materials but also concern social issues.[4] The units are easy to dismantle, and the mostly local materials can be easily disposed or recycled. The log houses in India show a particular feature. It was coated with a traditional mud floor. For the roof, split bamboo was applied to the rib vaults and whole bamboo to the ridge beams. A locally woven cane mat was placed over the bamboo ribs, followed by a clear plastic tarpaulin to protect against rain, then another cane mat. Ventilation was provided through the gables, where small holes in the mats allowed air to circulate. This ventilation also allowed cooking to be done inside, with the added benefit of repelling mosquitoes.

[4]This building method proved to be very cheap and therefore affordable: the cost of materials for one 52 square meter unit was below $2000.

8.8 From Fractals to Catastrophies

Eisenman and his followers, however, are interested not so much in practicing ecology but in processes as discussed in natural sciences, mathematics, and physics. In the 1980s, Eisenman aspired to a "tectonic literature" that will write itself, absolving him from the responsibility of authorship and the guilt of authority. To this effect, he proposed several design methods that attempted to dislocate the author from the work by replacing the designer's intentional choice with either aleatory systems or the impersonal determinism of an algorithm. A number of his projects, built and unrealized, were developed using scientific models: fractals in the *Wexner* Center in Columbus Ohio, 1989; the genome in the Biozentrum in Frankfurt, 1989; "Boolean" cubes for the Carnegie Mellon Research Institute in Pittsburgh; the "butterfly cusp" diagram of catastrophic events for the Rebstock Park Housing in Frankfurt, 1992; the Möbius strip for the Max Reinhardt Haus project for Berlin, 1993; and soliton wave studies for the Jörg Immendorff Haus in Duesseldorf, 1993.

The longest standing of these was his interest in the "scaling" aspect of fractal geometry. Borrowing the term from Mandelbrot, but ignoring the mathematician's intuition that "the fractal new geometric art shows surprising kinship to Great Master paintings or Beaux Arts architecture," Eisenman attempted to revive the avantgarde project by reading fractals as analogous to Jacques Derrida's deconstruction, and vice versa [25]. Eisenman believed that fractal geometry could overturn the "metaphysics of scale" in Western architecture, because the self-similarity of fractals destroyed the possibility of originality, an originary trace, and a decidably "real" scale [26]. This interpretation must, however, be rejected. If self-similar recursivity questions origin, so too do self-sameness, reflexivity, resemblance, or similitude in general, and fractals have no monopoly on dislocating origins. Furthermore, in Eisenman's projects such as the Wexner Center or Frankfurt Biozentrum, self-similarity was limited to but a few privileged points, while in fractal geometry, every point has that property. Finally, Eisenman introduced neither self-similarity nor the principle of scaling to architectural design. Charles Jencks points out that Bruce Goff "virtually invented fractalian architecture before the fact" in his design for the studio of Joe Price, overlaying of triangles, hexagons, trihexes, and lozenges [27]. In fact, the repetition of self-similar forms is found throughout architectural history, most evident in Gothic cathedrals and even in Greek and Egyptian temples.

Although scaling, folding, and other mathematically inspired design algorithms fail to bear out authorial claims about their fractal, deconstructive, rhizomatic, or scientific nature, they do make some progress toward realizing the ideal, proposed by both Hugo Häring and Stéphane Mallarmé (among countless others), of completely erasing the author and letting the work create itself in a natural, unmediated way [28]. Influenced by Hegelian philosophy, Mallarmé wrote to Henri Cazalis already in 1867, "I am impersonal now: not the Stéphane you once knew, but one of the ways the Spiritual Universe has found to see Itself, unfold Itself through what used to be me" [29].

In some of Eisenman's designs, such as his *Romeo and Juliet* project of 1986, the designer almost disappears, just letting various discourses, including Shakespeare's play and the city of Verona, to intersect and unfold in new combinations. Completed for the 1986 Venice Biennale, the project was to present the dominant themes of the Romeo and Juliet story in architectural form. Through the diagrammatic processes of superposition and scaling, the plan of the city of Verona was transformed to reveal the themes of Shakespeare's play.

While Eisenman's algorithmic designs have succeeded at times in displacing the author and disrupting the standard categories of architecture, his methods have been criticized by his own authority. Jacques Derrida accused Eisenman's scaling of being "totalizing first because it is structured as a closed narrative entirely determined by origin and end – it does not respect textual openness and indeterminacy. Secondly, scaling is an anathema because it is the vehicle by which Eisenman seeks to replace one totality, traditional design, with a new and different totality" [30].

Chastened, Eisenman and his followers moved from Mandelbrot's fractal geometry and Derrida's deconstruction to René Thom's catastrophe theory paired up with the philosophical ideas of Gilles Deleuze. In its emphasis on unpredictable, locally emergent properties which result from feedback loops and irreducible, nondecomposable diffusion of decisive factors, catastrophe theory seemed the ideal response to Derrida's charge of totalization in the scaling method. Inspired by D'Arcy Wentworth Thompson, René Thom had developed catastrophe theory as a way of addressing biological morphogenesis mathematically. Catastrophe theory can supply a number of descriptions of morphological transformations – provided they can be approximated by dynamic systems with fixed points as their attractors – but mathematicians are divided over the means of deciding whether observable discontinuity on the level of phenomena can be interpreted as a mathematical jump in the space of the attractors. However, Peter Eisenman's Max Reinhardt Haus project for Berlin (1993), which is partly based on these ideas, resembles the crystalline architecture of the Czech Cubist Pavel Janak.

The point has often been made that the architecture of Eisenman, Lynn, Chu, NOX, Marcos Novak, and others bears a certain formal similarity, for example, to the *Merzbau* of Kurt Schwitters, to Czech Cubism, to Boccioni's futurism, and to the chronophotographs of Etienne-Jules Marey. One of the reasons why the designs of the new avantgarde look so much like experiments of a 100 years ago might be that contemporary architects are still reading the same books, looking at the same pictures, and engaging in the same issues as the artists of around 1900.

Although most applications of catastrophe theory (by Christopher Zeeman and others) have produced empirically false predictions, this does not necessarily invalidate it as an explanatory paradigm. However, the application of catastrophe theory in architecture is a different ball game altogether, since we are dealing not with descriptive but normative issues. Robin Evans once suggested that Peter Eisenman's houses were not so much *analogs* to language as they were three-dimensional models of Noam Chomsky's *theory* of language. Eisenman's work in the 1980s can similarly be seen as attempts to petrify Jacques Derrida's beliefs about

trace, *différance* and effacement in concrete, steel, and glass [31]. His more recent applications of the work of Deleuze or Thom are not essentially different – the question is why these theories about natural or social processes, which they purport to describe, should be reproduced in architecture?

Different reasons have been proposed by contemporary writers. Greg Lynn suggests that architects should use complex curved and folded planes because recent advances in computer modeling have made topological descriptions of such forms accessible to non-mathematicians [28]. Why the mere possibility of drafting certain forms with precision would justify those forms is, however, unclear – unless one subscribes to a variation of the classic principle of plenitude (i.e., the thesis that all true potentialities need to be actualized) or to some kind of organicist belief that everything is interconnected and hence every innovation must have consequences in every domain of life.

A different defense for the use of chaos theory in architectural design is provided by Charles Jencks, who claims that the task of architecture is to tie human beings into the cosmos by building close to nature, thereby representing "the basic cosmogenic truth" of self-organization, emergence, and jumps to a higher level. Like Renaissance theorists, he insists that architecture must look to contemporary science for "disclosures of the Cosmic Code" and claims that Frank Gehry's design for the Guggenheim Museum at Bilbao reflects best the new paradigm. Only by looking "to the transcendent laws which science reveals," can architecture "get beyond the provincial concerns of the moment, beyond anthropomorphism and fashion" and "regain a power that all architecture has had" [32]. While ostensibly declaring avantgarde architecture to be as advanced and intellectually respectable as modern science, Jencks' New Age vision nevertheless relegates architecture to an inferior position, subordinate to natural science.

8.9 Form Follows Function

In order to fulfill the conditions of an organic unity or organic whole, it has been common in western architecture to make use of the proportions of natural beings rather than reproducing their forms. Vitruvius advocated basing the proportions of a building on those of a perfect man, establishing a tradition that inspired numerous reconstructions and revisions, the most famous one in modern architecture being Le Corbusier's *Modulor* of 1948, which overlaid the image of a man on the Fibonacci series, found in the shell of the spiral nautilus and which formed the basis of the golden section.

Yet in the eighteenth century, British empiricists had argued against the idea that architecture should imitate the proportions of natural organisms. In *A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful*, Edmund Burke argued that proportion is not the cause of beauty in vegetables, nor can the notion of architectural proportion be derived from the Vitruvian man. His major arguments against the Vitruvian doctrine ran as follows: "Men are very rarely seen in this

strained posture; it is not natural to them; neither is it at all becoming. – the view of the human figure so disposed, does not naturally suggest the idea of a square, but rather of a cross; – several buildings are by no means of the form of that particular square, which are notwithstanding planned by the best architects, and produce an effect altogether as good. [Finally, Burke concluded,] no two things can have less resemblance or analogy, than a man, and a house or temple: do we need to observe, that their purposes are entirely different?" [33].

Burke's tacit assumption was that if the purposes of a man and a house are different, then their forms should be different as well. In this, he relies on another Aristotelian commonplace: that an entity is defined by its *telos* or goal. For Aristotle, *ars imitatur naturam* meant that artists should work like nature – not by imitating the appearance of natural organisms, but by letting their creations unfold their own natures. If Aristotle is correct, nature does nothing in vain, "God and nature create nothing that has not its use" [34].

The fundamental tenet of functionalism that of designing "von innen nach aussen" agrees with Aristotelian essentialism [35]. Mediated by Romantic and Transcendental thought, the Aristotelian principle of creation was reformulated in 1896 by Louis Sullivan, "It is the pervading law of all things organic, and inorganic, of all things physical and metaphysical, of all things human and all things superhuman, of all true manifestations of the head, of the heart, of the soul, that the life is recognizable in its expression, that form ever follows function. This is the law." [36]. Many architects turned directly to nature to study somewhat optimized structures, in particular load bearing systems and streamline forms like so many projects by Buckminster Fuller (Dymaxion Car 1933, Dymaxion House 1945, Geodesic Dome in Montreal 1967) (Figs. 8.15–8.18). Tree structures and tent structures were also objects of investigation among modern architects. With his students, Frei Otto developed already in the early 1960 various concepts of branched pillars after the modell of trees. The feasibility study "Tree Structures" for an exhibition hall at Yale University, USA, in 1960 was further developed in the support pillars of a six-angle gridshell in the Kings Office at the Council of Ministers in Majlis al Shura, Riyadh, Saudi Arabia, 1979 (Frei Otto together with Rolf Gutbrod, Büro Happold, Ove Arup, and Partner).

Santiago Calatrava's designs are often inspired by nature, featuring a combination of organic forms and technological innovation. A good example is the Milwaukee Art Museum expansion, which incorporates multiple elements inspired by the Museum's lakefront location (Figs. 8.19 and 8.20). Among the maritime elements in Calatrava's design can be distinguished movable steel louvers inspired by the wings of a bird; a cabled pedestrian bridge with a soaring mast inspired by the form of a sailboat and a spider web and a curving single-storey galleria reminiscent of a skeleton or a wave. The smooth flight of a giant bird inspired the spectacular extension for the main building whose immense "wings" open and close with the museum. More or less the same form is repeated in his vision for a Port Authority transit hub in New York City (Fig. 8.21). A comparable bird-like structure seems to be also the basis of the Qatar Photography Museum, which opens and closes

Fig. 8.15 Buckminster Fuller, Dome and Car, Bilderarchiv Institut für Architekturwissenschaften, TU Wien

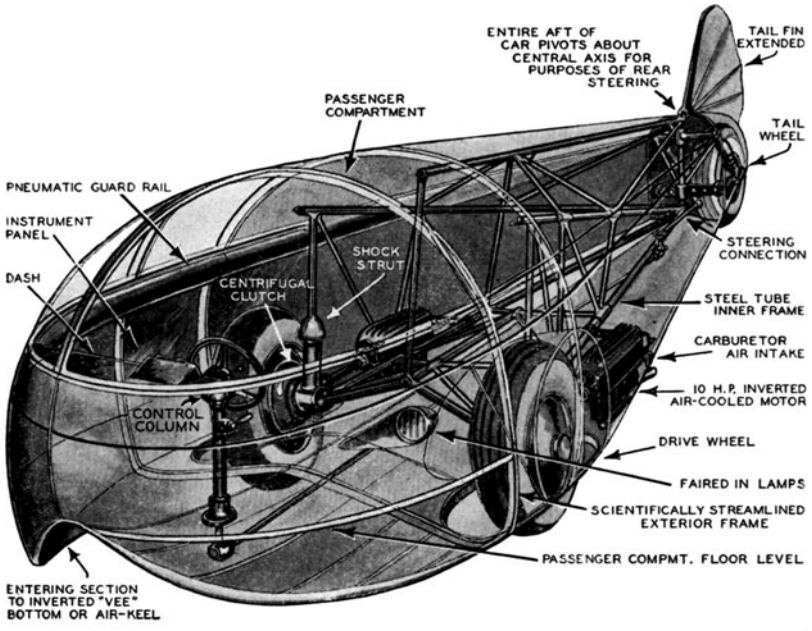

Fig. 8.16 Buckminster Fuller, Dymaxion Car, Bilderarchiv Institut für Architekturwissenschaften, TU Wien

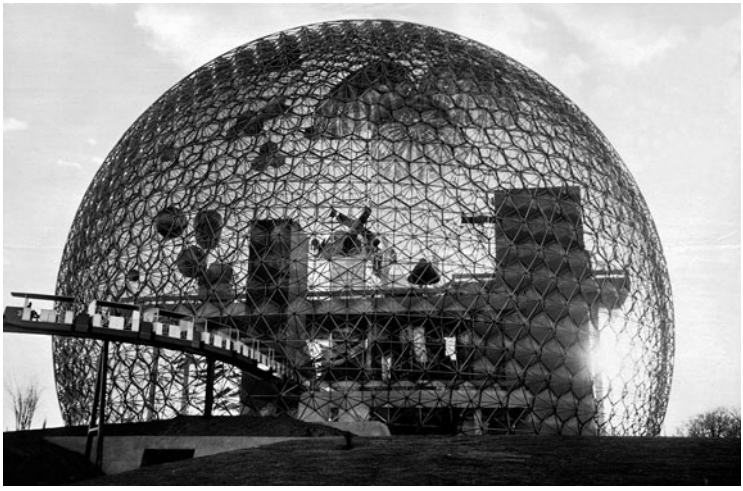

Fig. 8.17 Buckminster Fuller, Geodesic Dome, Bilderarchiv Institut für Architekturwissenschaften, TU Wien

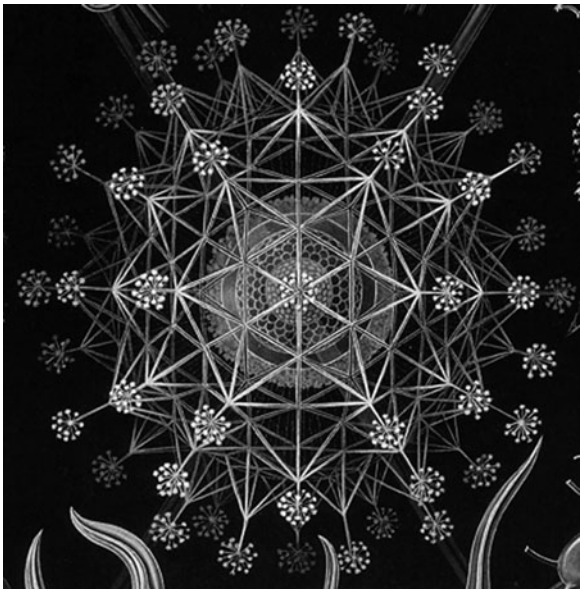

Fig. 8.18 Ernst Haeckel, Detail from Art Forms in Nature, Bilderarchiv Institut für Architekturwissenschaften, TU Wien

depending on the amount of sunlight. The key idea of the Museum of Photography is an ultra-light structure consisting of two immense curved "wings" which will open and close with the light, fine-tuned to the needs of the exhibitions, just like the lens of a camera, which goes back to the movement of the pupil.

Fig. 8.19 Santiago Calatrava, Art Museum Milwaukee, © calatrava architects

8.10 The Concept of Organic Unity

In architectural theory, the notion of *organic unity* was accepted on Aristotle's authority until the nineteenth century, when new interpretations were proposed on the basis of contemporary biology. Paraphrasing the biologist Georges Cuvier, the architect Eugène-Emmanuel Viollet-le-Duc wrote: "Just as when seeing the leaf of a plant, one deduces from it the whole plant; from the bone of an animal, the whole animal; so from seeing a cross-section one deduces the architectural members; and from the members, the whole monument" [37].

This argument was later repeated by Adolf Loos, who claimed that one could reconstruct an entire society from a single button.

Both Gottfried Semper and Viollet-le-Duc turned to biology to argue their position in the debate as to whether form follows function or vice versa. This debate began in the 1830s with the establishment of morphology and comparative anatomy. While Cuvier proposed the "form follows function" theory, his rival Etienne Geoffroy Saint-Hilaire insisted one could not draw conclusions for the structure by looking at the function, arguing that no matter what their function, all organic forms could be reduced back to original types. In this conviction, he came close to Goethes earlier theory of the *Urpflanze*, the original plant.

Fig. 8.20 Santiago Calatrava, Art Museum Milwaukee, interior, Bilderarchiv Institut für Architekturwissenschaften, TU Wien

By the 1840s, biologists rejected both Cuvier's and Saint-Hilaire's position and questioned in general the validity of teleological interpretations of natural phenomena. Contrary to the theses of Viollet-le-Duc and Cuvier, an investigation of any organism immediately reveals an arbitrary number of parts, shape, structure, or function of which allow for no adequate explanation. Yet, despite the efforts of a century of Darwinism to present evolution as a process involving the random mutation of genes, with natural selection weeding out only those mutations that fatally affect populations, many organicist writers continue to view evolution as a teleological process of improvement in which organisms have achieved a perfect adaptation to their environment – permitting some ecologists to take it as axiomatic that all ecosystems are in perfect homeostasis, only upset by the thoughtless interventions of humankind. Such an idea of nature, as a perfectly functioning ecological complex, is not derived from empirical observation but rather from extra-scientific, usually theological, sources.

Fig. 8.21 Santiago Calatrava, NYC, Transportation Hub, © Courtesy of the Port Authority of New York and New Jersey

Be that as it may, the Aristotelian ideal of an organic whole has pervaded modern architecture, even the theories of architects who never used natural forms in their designs. Thus, Ludwig Hilberseimer, for example, demanded that "all works, however different, must originate in a unified spirit" [38]. Similarly, Ludwig Mies van der Rohe defining a structure turns to the Aristotelian concept of organic wholes when he says, "by structure we have a philosophical idea. The structure is the whole, from top to bottom, to the last detail with the same ideas" [39].

In what is perhaps the most virulent formulation of organicism, the philosophy of G.W.F. Hegel, the concept is understood in terms of the interconnectedness or the essential fragmentary nature of everything as Richard Shusterman pointed out: In his *Logic*, Hegel wrote: "Everything that exists stands in correlation, and this correlation is the veritable nature of every existence. The existent thing in this way has no being of its own, but only in something else" [40, 41].

According to the British philosopher George Edward Moore, the Hegelian notion of an organic unity claims that "just as the whole would not be what it is but for the existence of its parts, so the parts would not be what they are but for the existence of the whole" [41, 42]. The idea is that emergent properties belong to the parts as well as the whole. A severed hand, for example, cannot function at all in the way we expect of a hand. Things with different properties must be different things, so that a hand severed from its body detached is not the same thing as a hand still connected.

Hence, parts of an organic whole (in the Hegelian sense) are inconceivable, except as parts of that whole.

Yet Moore rejected this view, because it confuses properties belonging to the whole with properties of one of its parts. Even more significantly, he viewed the Hegelian notion of an organic whole as self-contradictory, because it assumes that a part is distinguishable from the whole while simultaneously asserting that the part contains some aspects of that whole as part of itself. In other words, radical organicism postulates that any individual part we distinguish as an element in the whole cannot be so distinguished – the part *is*, it is not part of a whole.

Obviously, Derrida's theories are a form of radical organicism, based on the universalization of Ferdinand de Saussure's diacritical linguistics or Friedrich Nietzsche's belief that "in the actual world [. . .] everything is bound to and conditioned by everything else" and his conclusion that "no things remain but only dynamic quanta, in a relation of tension to all other dynamic quanta: their essence lies in their relation to all other quanta" [41, 43].

We have already seen that radical ecology makes similar claims for biological systems. In Derrida's hands, organic diacriticism leads, among other things, to the dissolution of the work of art as an independent entity, as defined by modernist criticism.

Hence, the very concept of an organic unity is self-contradictory. Yet, even post-structuralist writers accept the notion in their critical practice, for the assumption of unity is required of the concept of a work of art which in turn forms the basis of the interpretive activity [44–46]. The concept of organic unity is therefore inexorably bound with the concept of a work of art – only if taken as a unity does a thing exist as a work of art [47]. In the same way, Mies van der Rohe compared different types of buildings to roses and potatoes, explaining that, "while both are based on the same natural principles, we ask of a rose only that it be a rose; we ask of a potato only that it be a potato. Philosophically speaking, only then do they exist." [48].

8.11 Conclusion

Despite their authors' claims of producing something radically new, many of the design strategies applied by the current architectural avantgarde can be traced back to one of the oldest and most influential ideas in architectural history: the concept of organicism in its various guises. Aristotle's definition of art as the imitation of nature provided the unquestionable premise for two millennia of architecture.

While attempts to base architectural design on the example of nature are typical of stylistic crises and indicative of a search for new, possibly objective foundations, the implications of organicism are not limited to particular styles or forms [49–51]. Rather, they are general and fundamental enough to relate to contemporary issues at any time and pose radical questions. More recently, the challenge of *ars imitatur naturam* focuses on the author and the object, sustainability, and imitation of natural processes.

The objective of following "nature" as revealed through the natural sciences or the "nature" (essence) of the particular building de-emphasizes the authorial self-expression of the architect and ultimately leads to the "death of the author," as announced by Roland Barthes in the artistic context or the reconstruction of natural materials and processes within the structural context. The notion of a building as a functional unity comparable to an organism necessitates a questioning, on one hand, of what is a function, how it is historically, physically and socially constituted, and what would qualify as a functional unit of study, and on the other hand, how body, function, and building and the chiasmatic relationships between them may be articulated. If the argument sketched above is correct, the assumption of the building as an autonomous entity or an independent whole has soon to be given up.

References

1. D.W. Thompson, *On Growth and Form* (Cambridge University Press, Cambridge, 1942), p. 16
2. Aristotle, *De Partibus Animalum* and *De generatione* (Clarendon, Oxford, 1972) (407b1; cf. *Pol*. 1325b10)
3. Aristotle, *Ethica Nicomachea (Nicomachean Ethics)*, trans. with commentaries and glossary ed. by H.G. Apostle (Peripatetic Press, Grinnell, 1984), p. 1168a7 and S.R.L. Clark, *Aristotle's Man. Speculations upon Aristotelian anthropology* (Clarendon Press, Oxford, 1975), p. 62
4. G. Leopardi, "A se stesso." The translation is Jormakka's; the original is as follows: "Omai disprezza/Te, la natura, il brutto/Poter che, ascoso, a comun danno impera/E l'infinita vanità del tutto," in *Selected Prose and Poems*, ed. by I. Origo, J. Heath-Stubbs (Oxford University Press, London, 1966), p. 280
5. C. Thacker, *The Wildness Pleases. The Origins of Romanticism* (Croom Helm, London and Canberra; St. Martin's Press, New York, 1983), p. 88
6. Le Corbusier, *L'art decoratif d'aujourd'hui*, éd. by Arthaud (Paris, 1980), p. 176
7. K. Jormakka, D. Kuhlmann, O. Schuerer, *Design Methods (Basics)* (Birkhäuser, Basel, 2007), p. 9ff
8. G. Lynn, *An Advanced Form of Movement*, in *Architectural Design*, vol. 67 (1997), p. 54ff
9. G. Lynn, Animate form. *Faultlines*. UCLA Department of Architecture and Urban Design. 1997, vol. 1, No. 2, p. 1ff
10. H. Bergson, Creative evolution (L'Evolution créatrice) (1907)
11. F. Otto, Biology and Building 2. Practical application of analogous research. From hydrostatic skeleton to skeletal muscle system. Sandwich structures within bird skulls. The principles of lightweight structures in organisms. Static of extremities. IL 4, University of Stuttgart, Germany, Otto, Frei, (1973), Pneu and Bone IL University of Stuttgart, Germany, J. Glancey, The lightweight champion of the world. *The Guardian* (Monday 4 October 2004) (1972) http://www.guardian.co.uk/artanddesign/2004/oct/04/architecture
12. P. Sloterdijk, *Sphären. Eine Trilogie* (Suhrkamp Verlag, Frankfurt, 2005)
13. R. Banham, Zoom wave hits architecture. New Soc. (1966)
14. L.H. Sullivan, *Kindergarten Chats and other Writings* (Dover Publications, New York, 1979), p. 188
15. D. Sharp, Organische Architektur — eine Art, Natur zu verstehen und wiederzugeben? *Archithese* **5**, 17 (1988)
16. W.C. Behrendt, *Modern Building* (Harcourt, Brace and Company, New York, 1937), p. 11f
17. B. Zevi, *Towards an Organic Architecture* (Faber & Faber, London, 1950)
18. B. Mandelbrot, *The Fractal Geometry of Nature* (W.H. Freeman, San Francisco, 1982)

19. B. Mandelbrot, Fractal as a morphology of the amorphous, in *Fractal Landscape from the real World*, ed. by B. Hirst (Cornerhouse, Manchester, 1994)
20. A. Vidler, Homes for cyborgs: domestic prostheses from Salvador Dali to Diller and Scofidio. Ottagono **96**, 37–38 (1990)
21. P. Gruber, *Biomimetics in Architecture [Architekturbionik] – the architecture of life and buildings*, Doctoral thesis, Vienna University of Technology, 2008
22. D. Haraway, A cyborg manifesto: science, technology, and socialist-feminism in the late twentieth century, in *Simians, Cyborgs and Women: The Reinvention of Nature* (Routledge, New York, 1991), p. 149
23. M. Gandy, Cyborg urbanization: complexity and monstrosity in the contemporary city. Int. J. Urban Regional Res. **29**(1), 28 (2005)
24. A. Vidler, *The Architectural Uncanny, Essays in the Modern Unhomely* (MIT Press, Cambridge, 1992), p. 147
25. B. Mandelbrot, Fractal as a morphology of the amorphous, in *Fractal Landscape from the real World*, ed. by B. Hirst (Cornerhouse, Manchester, 1994)
26. P. Eisenman, *Moving Arrows, Eros, and Other Errors: An Architecture of Absence* (Architectural Association, London, 1986), p. 4
27. C. Jencks, *The Architecture of the Jumping Universe* (Academy Editions, London, 1995), p. 44
28. K. Jormakka, Total control and chance in architectural design. Acta Polytech. Sc. **99**, 35–41 (1994)
29. S. Mallarmé, in *Selected Poetry and Prose*, ed. by M.A. Caws (New Directions Books, New York, 1982), p. 87
30. J. Derrida, Why Peter Eisenman writes such good books. *A + U* E8088, p. 114 (1988)
31. R. Evans, Not to be used for wrapping purposes. AA Files **10**(69), 69 (1985)
32. C. Jencks, *The Architecture of the Jumping Universe* (Academy Editions, London, 1995), p. 167ff
33. E. Burke, *A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful* (F.C. and J. Rivington, et al., London, 1812) pp. 164ff and 183f
34. T. Aquinas, *Commentary on Aristotle's Physics*, trans. R. J. Blackwell, intro. V. J. Bourke (Yale University Press, New Haven, 1963) (II,4; Aristotle (1993) *De Caelo* 271a35; *De Part.An*.645a23–26; 639bl9)
35. H. Häring, in *Schriften, Entwürfe, Bauten*, ed. by H. Lauterbach, J. Joedicke (Karl Krämer Verlag, Stuttgart, 1965), pp. 8 and 13f
36. L.H. Sullivan, *Kindergarten Chats and other Writings* (Dover Publications, New York, 1979), p. 208
37. E.E. Viollet-le-Duc, *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle* (A. Morel, Paris, 1875–1882)
38. L. Hilberseimer, *Groszstadtarchitektur* (Hoffmann, Stuttgart, 1978), p. 99ff
39. P. Carter, Mies van der Rohe. An appreciation on the occasion this month, of his 75th birthday. Arch. Des. **1**, 97 (1961)
40. G.W.F. Hegel, *Hegel's Logic*, trans. W. Wallace (Oxford University Press, Oxford, 1975), p. 191
41. R. Shusterman, *Pragmatist Aesthetics. Living Beauty, Rethinking Art* (Blackwell, Oxford, 1992), p. 72
42. G.E. Moore, *Principia Ethica* (Cambridge University Press, Cambridge, 1959), p. 33
43. F. Nietzsche, *The Will to Power* (Vintage Books, New York, 1968) Sect. 559, 584, 635
44. G. Dickie, *Evaluating Art* (Temple University Press, Philadelphia, 1988), pp. 164–165
45. W.K. Wimsatt, M.C. Beardsley, The intentional fallacy, in *Critical Theory Since Plato*, ed. by H. Adams (Harcourt Brace Jovanovich, New York, 1971), p. 1015
46. A.C. Danto, *Beyond the Brillo Box* (Farrar Straus Giroux, New York, 1992), p. 134
47. K. Jormakka, How to read (Anything as) art. Nordic J. Arch. Res., **7**(2), 38–45 (1994)
48. F. Neumeyer, *The Artless Word. Mies van der Rohe on the Building Art*, trans. M. Jarzombek (MIT Press, Cambridge, 1991), p. 299

49. C. van Eck, *Organicism in 19th Century Architecture* (Architectura & Natura Press, Amsterdam, 1994)
50. D. Kuhlmann, *Lebendige Architektur* (Bauhaus Universität Weimar Verlag, Weimar, 1998)
51. D. Kuhlmann, K. Jormakka, *Ars Imitatur Naturam*, Thesis, vol. 6 (Bauhaus Universität Weimar Verlag, Weimar, 1997), pp. 6–13

Literature

T. Aquinas, *Commentary on Aristotle's Physics*, trans. R. J. Blackwell, intro. V. J. Bourke (Yale University Press, New Haven, 1963)
Aristotle, *De Partibus Animalum* and *De generatione* (Clarendon, Oxford, 1972)
Aristotle, *Ethica Nicomachea (Nicomachean Ethics)*, trans. with commentaries and glossary ed. by H.G. Apostle (Peripatetic Press, Grinnell, 1984)
Aristotle, *De Caelo. (On the heavens)*, trans. W.K.C. Guthrie (William Heinemann, London, 1993)
W.C. Behrendt, *Modern Building* (Harcourt, Brace and Company, New York, 1937)
E. Burke, *A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful* (F.C. and J. Rivington, et al., London, 1812)
P. Carter, Mies van der Rohe. An appreciation on the occasion this month, of his 75th birthday. Arch. Des. **1**, 97 (1961)
S.R.L. Clark, *Aristotle's Man. Speculations upon Aristotelian anthropology* (Clarendon Press, Oxford, 1975)
A.C. Danto, *Beyond the Brillo Box* (Farrar Straus Giroux, New York, 1992)
J. Derrida, Why Peter Eisenman writes such good books. *A + U* E8088, p. 114 (1988)
G. Dickie, *Evaluating Art* (Temple University Press, Philadelphia, 1988)
C. van Eck, *Organicism in 19th Century Architecture* (Architectura & Natura Press, Amsterdam, 1994)
P. Eisenman, *Moving Arrows, Eros, and Other Errors: An Architecture of Absence* (Architectural Association, London, 1986)
R. Evans, Not to be used for wrapping purposes. *AA Files* **10**(69), 69 (1985)
M. Gandy, Cyborg urbanization: complexity and monstrosity in the contemporary city. Int. J. Urban Regional Res. **29**(1), 26–49 (2005)
J. Glancey, The lightweight champion of the world. *The Guardian* (Monday 4 October 2004). http://www.guardian.co.uk/artanddesign/2004/oct/04/architecture
H. Häring, in *Schriften, Entwürfe, Bauten*, ed. by H. Lauterbach, J. Joedicke (Karl Krämer Verlag, Stuttgart, 1965)
D. Haraway, A cyborg manifesto: science, technology, and socialist-feminism in the late twentieth century, in *Simians, Cyborgs and Women: The Reinvention of Nature* (Routledge, New York, 1991)
G.W.F. Hegel, *Hegel's Logic*, trans. W. Wallace (Oxford University Press, Oxford, 1975)
L. Hilberseimer, *Groszstadtarchitektur* (Hoffmann, Stuttgart, 1978)
C. Jencks, *The Architecture of the Jumping Universe* (Academy Editions, London, 1995)
K. Jormakka, Total control and chance in architectural design. Acta Polytech. Sc. (1994a)
K. Jormakka, How to read an object as art. Nordic J. Arch. Res. (1994b)
K. Jormakka, D. Kuhlmann, O. Schuerer, *Design Methods (Basics)* (Birkhäuser, Basel, 2007)
D. Kuhlmann, K. Jormakka, *Ars Imitatur Naturam*, Thesis, vol. 6 (Bauhaus Universität Weimar Verlag, Weimar, 1997), pp. 6–13
D. Kuhlmann, *Lebendige Architektur* (Bauhaus Universität Weimar Verlag, Weimar, 1998)
Le Corbusier, *L'art decoratif d'aujourd'hui*, éd. by Arthaud (Paris, 1980), p. 176
Leopardi, G. (1966) in *Selected Prose and Poems*, ed. by I. Origo, J. Heath-Stubbs (Oxford University Press, London, 1966)
G. Lynn, *An Advanced Form of Movement*, in *Architectural Design*, vol. 67 (1997), pp. 54–59

G. Lynn, Animate form. *Faultlines.* UCLA Department of Architecture and Urban Design. 1997, vol. 1, No. 2, p. 1ff
S. Mallarmé, in *Selected Poetry and Prose*, ed. by M.A. Caws (New Directions Books, New York, 1982)
B. Mandelbrot, *The Fractal Geometry of Nature* (W.H. Freeman, San Francisco, 1982)
B. Mandelbrot, Fractal as a morphology of the amorphous, in *Fractal Landscape from the real World*, ed. by B. Hirst (Cornerhouse, Manchester, 1994)
G.E. Moore, *Principia Ethica* (Cambridge University Press, Cambridge, 1959)
F. Neumeyer, *The Artless Word. Mies van der Rohe on the Building Art*, trans. M. Jarzombek (MIT Press, Cambridge, 1991)
F. Nietzsche, *The Will to Power* (Vintage Books, New York, 1968)
F. Otto, *Biology and Building 2. Practical Application of Analogous Research*. IL 4, (University of Stuttgart, Germany, 1972)
F. Otto *Pneu and Bone. The Structural System Pneu in Living Nature*. IL 35, (University of Stuttgart, Germany, 1995)
D. Sharp, Organische Architektur — eine Art, Natur zu verstehen und wiederzugeben? *Architheses* **5**, 17 (1988)
R. Shusterman, *Pragmatist Aesthetics. Living Beauty, Rethinking Art* (Blackwell, Oxford, 1992)
P. Sloterdijk, *Sphären. Eine Trilogie* (Suhrkamp Verlag, Frankfurt, 2005)
L.H. Sullivan, *Kindergarten Chats and other Writings* (Dover Publications, New York, 1979)
C. Thacker, *The Wildness Pleases. The Origins of Romanticism* (Croom Helm, London and Canberra; St. Martin's Press, New York, 1983)
D.W. Thompson, *On Growth and Form* (Cambridge University Press, Cambridge, 1942)
Vidler, A, Case per cyborg: protesti domestiche da Salvador Dali a Diller e Scofidio [Homes for cyborgs: domestic prostheses from Salvador Dali to Diller and Scofidio]. *Ottagono* 96, 36–55 (1990)
A. Vidler, *The Architectural Uncanny, Essays in the Modern Unhomely* (MIT Press, Cambridge, 1992)
E.E. Viollet-le-Duc, *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle* (A. Morel, Paris, 1875–1882)
W.K. Wimsatt, M.C. Beardsley, The intentional fallacy, in *Critical Theory Since Plato*, ed. by H. Adams (Harcourt Brace Jovanovich, New York, 1971)