Architectural
Histories

Halland, I. 2024. The Delos Mutation: Interdisciplinary Entanglements between Biology and Architecture 1963–1975. *Architectural Histories*, 12(1): pp. 1–22. DOI: https://doi.org/10.16995/ah.10487

Open Library of Humanities

The Delos Mutation: Interdisciplinary Entanglements between Biology and Architecture 1963–1975

Ingrid Halland, The Oslo School of Architecture and Design, Norway, Ingrid.Halland@aho.no

This article traces the interdisciplinary entanglement between biology and architecture at The Delos Symposion, a series of annual week-long architecture and urbanism symposia convened by architect and planner Constantinos Doxiadis (1913–1975), ten of which took place on a cruise ship in the Mediterranean Sea between 1963 and 1972. These Delos symposia stand out as a pioneering interdisciplinary initiative and a unique think-tank for future-oriented developments in both architectural theory and biology, united by a common interest in cybernetics. Biologist Conrad Hal Waddington (1905–1975), who attended all ten Delos gatherings, was a forerunner of such new developments in biology; at Delos he discussed how his ground-breaking theory of epigenetics would change how designers would build, plan, and conceptualize buildings and cities.

This article is a critical study of how Waddington's epigenetic theory mutated into architecture and urban theory. First, I discuss Doxiadis' holistic urban theory of ekistics in relation to Waddington's epigenetic theory by focusing on the notion of open-endedness in the two theories. The article then argues that the discussions on planning and design at Delos affected Waddington's thinking, changing a structural belief in planning into a post-structural disbelief in certitude. The interdisciplinary Delos discussions about planning and architecture triggered the scientist to turn toward aesthetics and ethical epistemology as a response to an uncertain future — a transmutation that impelled ethical and epistemological developments that still resonate in critical discourses in the humanities.

Keywords: Urban theory; 1960s; biology; cybernetics; epigenetics; epistemology

Introduction

A photograph from 1963 taken at the Temple of Apollo at the ancient site of Didyma, in present-day Turkey, captures an unexpected meeting between two men. Conrad Hal Waddington (1905–1975), a biologist, and Constantinos Doxiadis (1913–1975), an architect and urban planner, are standing side by side, observing a circular floor carving **(Figure 1)**. Described as a *locus ludi*, Didyma is filled with artifacts relating to ancient games.[1] The two men, previously unknown to each other, seemed to share a common interest in the carved symbol **(Figure 2)**. Perhaps Doxiadis is pointing out the similarity between the symbol and his drawings of a static city **(Figure 3)**, and perhaps Waddington is amused by the circle's similarity to that of a visual representation of a cell. Didyma in Greek means 'twin'. As it turned out, the two men discovered a 'twin' in each other, originating in theoretical and also — perhaps surprisingly — disciplinary parallels, starting from a common ground in cybernetic thinking.

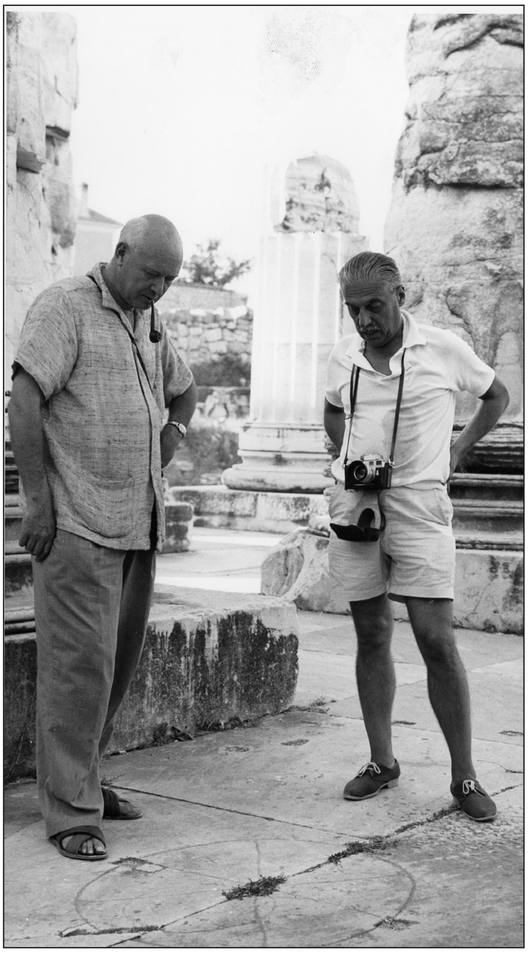

Figure 1: Constantinos Doxiadis and Conrad Waddington at the Temple of Apollo at Didyma, during the 1963 Delos Symposion. Constantinos A. Doxiadis Archives, Photographs 31252. © Constantinos and Emma Doxiadis Foundation.

In the late 1960s and early 1970s, the interdisciplinary entanglement between architecture and cybernetics motivated architectural experimentation with what Larry Busbea calls 'responsive environments' (Busbea 2020), that is, architecture both conceptually and formally based on open-endedness (see for instance Blakinger 2019; Hight 2007; Sadler 2016; Scott 2016; Steenson 2017; Wigley 2015). Arindam Dutta calls this the 'techno-social moment' in architecture (Dutta 2013,) and previous research has unpacked the close connection between architecture, cybernetics, and neoliberal economies (Martin 2003; Ulak 2023). Several formal developments in design have been claimed to be connected to this

Figure 2: Present-day photograph of the circle in Didyma. Courtesy of "Locus Ludi: The Cultural Fabric of Play and Games in Classical Antiquity", European Research Council (ERC) ERC Advanced Grant 2017-2022/2023.

entanglement, such as modular plastic architecture (Farantatos 2022; Halland 2020) and spongelike materials (Busbea 2017). Cybernetics is tightly connected to general, synchronic, and external currents in and of the humanities that urged epistemological reorientations of both subjectivity and objectivity (Clarke 2014; Halpern 2014; Hayles 1999). These cybernetic developments were, however, closely related to a branch of biology called systems biology. Architecture, planning, and urban theory have always been profoundly interdisciplinary disciplines; however, in architectural history, the impact from disciplines outside the field of architecture is often overlooked, as Anna Ulak shows in the article 'Diagrammatic Abstractions' (2023).

This article focuses on a unique interdisciplinary entanglement that has been left undiscussed in previous scholarship that grapples with cybernetics and architecture. By discussing the meeting between Waddington and Doxiadis at the interdisciplinary annual seminars called the Delos Symposion,[2] the article unfolds the conceptual and epistemological development of theories — from cybernetic theory to Doxiadis' urban theory called 'ekistics' to Waddington's biological theory called 'epigenetics' — to show how theories and concepts respond to interdisciplinarity in the same manner as biological systems response to environmental changes; sometimes changes are absorbed, but sometimes, often spurred by a crisis, creative mutations generate theories anew.

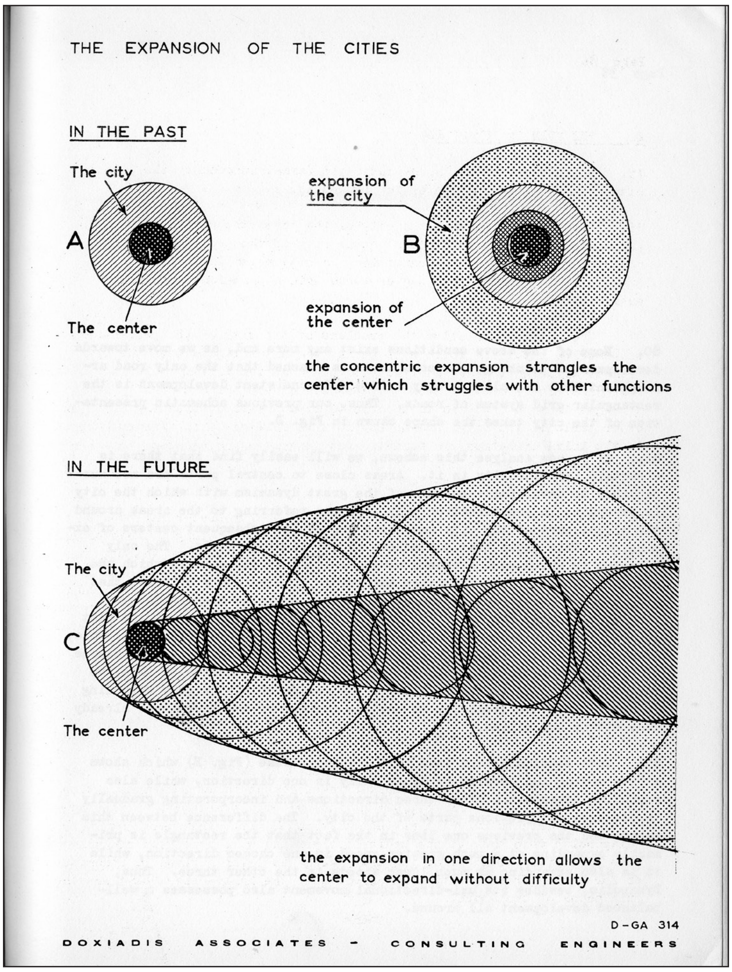

Figure 3: The expansion of the cities. From Doxiadis (1960: 37)/ Constantinos A. Doxiadis Archives, Articles-Papers 2529). © Constantinos and Emma Doxiadis Foundation.

New Uncertainties, New Methods

> The world has been in a state of chaos for so long that hardly anybody seems very conscious of what is new in the crisis phasing us today — a crisis arising from the explosion of world population, the explosion of population mobility, the explosion of productivity, the explosion of scientific knowledge, all growing at a pace which holds, perhaps, a greater threat to mankind than even the H-bomb, but which appears so slow and inevitable in its approach that few people care to think about it, let alone plan to control it. ('Meeting in Delos' 1963: 362)

The above quote from *The Architect's Journal* could be an account of contemporary crises arising in the wake of climate change, neo-liberalism, and post-truth society. Instead, it is from an article written almost sixty years ago: a report of the first of the Delos Symposion in August 1963. This interdisciplinary seminar, one week every summer on a cruise ship for 10 summers between 1963 and 1972,[3] gathered world-leading scientists, intellectuals, architects, and planners for discussions on how to develop global plans for urban development in light the quite recent realization that the world's population would grow immensely in the coming century. The ethos of urgency to discuss, plan, act, and thus control the forthcoming population crisis seemed resolute. The overall goals of the Delos Symposion were as ambitious as they were manifold and complex: Earth was facing new kinds of complex problems caused by population growth, so how could this state of global complexity be addressed? According to Doxiadis, who convened that first meeting, the situation was entirely multidimensional and therefore could not be addressed by fragmenting the problem into separate elements. Moreover, the novelty of the extraordinarily complex, intertwined crises obstructed the prospect of grasping the totality of the situation with any known methods or conceptual framework. Conventional scientific methods could not be used to account for a threat 'greater than the H-bomb'. New kinds of questions needed to be asked, new methodological approaches needed to be developed, and even the philosophical underpinnings of these methodological approaches — the ethics and epistemology — needed to be radically reconfigured. For Doxiadis, a starting point for developing new interdisciplinary approaches to the forthcoming complex challenges was a self-invented research field he named 'ekistics', meaning the science of human settlements. Doxiadis' ekistics was both a holistic theory for understanding the dynamics between human settlements, population growth, and global urbanism and a methodological planning tool for real-life development, as introduced in his book *Ekistics: An Introduction to the Science of Human Settlements*, published in 1968 (for previous research on Doxiadis, see Pyla 2002; Theodosis 2015; Tsiambaos 2018).

When the architectural theorist Siegfried Giedion opened his paper at the first Delos meeting in 1963 by locating the danger of our age in the complexity of its problems, it must have sounded like a familiar concern to the crowd of interdisciplinary scholars (Mead et al. 1963: 256). In Doxiadis' book *Architecture in Transition*, which was published the same year, the author argued that the present age was one of confusion, with the world experiencing a new kind of uncertainty. Something new was taking place, something not yet intelligible. An old system of thought was on the way out, but the new one was not yet discernible. The core argument of Doxiadis' book was that five problems — population growth, economic development, socialization, urbanization, and industrialization and technological progress — were fully entangled with each other. This meant that no single architectural action addressing just one or two of the factors would have any effect on the whole. The problems depended on each other and reinforced each other, and indeed this entanglement was a precondition for their emergence and for their potential solution. In the words of Doxiadis, this represented a 'coexistence of many forces ... : a dynamic situation which creates a host of problems for every aspect of our lives' (Doxiadis 1963: 57). Interestingly, Doxiadis questioned if the current scientific discourse was guilty of fostering conceptual notions of stability and linear causality, thereby directing attention away from the actual complexity of the challenges. Dynamic problems needed dynamic solutions, yet since the planet's problems were all interrelated, the solution should be *one* dynamic, interdisciplinary synthesis (145). Doxiadis found this new synthesis in general systems theory, and he affirmed at the end of *Architecture in Transition* that 'cybernetics and other new theories will gradually facilitate our better understanding of the complex problems we are facing' (191).

From Cells to Cybernetics

When Doxiadis invited Waddington to the first Delos symposium for discussions on the 'problem of the evolution of human settlements', Waddington responded enthusiastically about the interdisciplinary methods of approach. The initial aim of Doxiadis was to gather well-known scholars for a 'discussion between people coming from different professions, representing different interests, and different disciplines, and coming from different national backgrounds' (Doxiadis to Waddington, 5 March 1963, Waddington Papers). The idea of gathering, in Doxiadis' words, 'different classes' to discuss forthcoming problems of world settlements must have corresponded with Waddington's political standpoint. For decades, Waddington had been associated with the so-called 'new left' in the natural sciences, as noted by Donna Haraway in her 1975 article on British leftist scientific communities in 1930s: 'The British scientific left was made up by men such as Joseph Needham, J.B.S Haldane, J.D. Berhal, Lancelot Hogben, and C.H. Waddington: all workers of considerable fame in their own fields' (Haraway 1975: 443). Waddington's commitments were deeply entrenched. Haraway characterized this group of scientists as 'radical Marxists' and emphasizes that

> Waddington's [influential book] *The Scientific Attitude* and Bernal's *The Social Function of Science* were both the most explicit and the most influential tracts pointing to the promise of scientific reason in a socialist state, or more generally, for Waddington, in a well-run liberal state based on devotion of the greatest good for the greatest number, quantitively determined of course. (Haraway 1975: 444)

When Waddington received the invitation to participate at the first Delos symposium, he was at the pinnacle of a long academic career as a renowned leftist biologist,[4] but was as yet unfamiliar with the work of Doxiadis and his ekistic theories. It is possible that Waddington's wife, Justin Blanco White (1911–2001), encouraged him to accept the initial invitation. White was a practicing modernist architect educated at the Architectural Association who pioneered developments in the standards for low-cost housing while working at the Scottish Office and the Civil Service in Edinburgh.[5] In the end, the British biologist attended eight out of the ten Delos gatherings, most of the time accompanied by White, who gained the official status of a 'symposion observer' during her attendances.

It is also likely that the notion of complexity, an interest he shared with Doxiadis, initially impelled Waddington to first attend the Delos symposium, since throughout his career as a leading biologist he had insisted that the field of biology was more complex than other fields of the natural sciences. Waddington differentiated his own discipline from physics and chemistry by emphasizing how other branches of the natural sciences were mainly concerned with repetitive processes: 'They observe and analyse how the wheels go around: rather rarely, and only to a minor extent, are they confronted by systems which can be said to be built up or develop' (Waddington 1969b: 106). For Waddington, biology was something more than the study of the succession of repeated processes. By its very nature, he repeatedly claimed, the field of biology is not only processual, but it deals with continuous change; biology studies the mechanisms of growth and change by observing how organisms irreversibly metamorphose from one form to another. From the 1930s onward, Waddington was a pioneer in developing the field of systems biology, a sub-discipline of biology closely connected with developments in cybernetics and general systems theory.

The interdisciplinary, and highly diverse, field of research cybernetics can be defined as the science of complex systems and the control of these systems. In brief, both cybernetics and systems theory use systems to understand complex phenomena and problems. The theory focuses on a system's structure rather than its function. It assumes that complex systems share similar organizing principles despite different purposes, and that these principles can be mathematically modelled. Early cybernetic theory originated in the 1940s as a framework for understanding control and communication within self-regulated systems in both animate and inanimate realms (Wiener 1948; Ashby 1956). The field of research is intimately related to the holistic bio-semiotics of Jakob von Uexküll, and in the 1950s and 1960s cybernetics became connected to more general and diverse currents of research (see Hayles 1999; Clarke 2014). This underlying cybernetic apparatus, then, was implemented throughout different epistemological paradigms, for example in engineering studies and humanities as well as natural and social science. This led to an efflorescence of cybernetic-inflected propositions and models, for example in pure mathematics, applied business cases, information and communication theory, the development of technical instruments, the organization of laboratories and other institutions, and graphic visualizations of research models and results (on diagrams, see Ulak 2023). Yet despite the diversity of this field of study, the development of advanced machine technology had an especially prominent position in the development of cybernetics. New and exceedingly complex technical advances required a new set of theories to comprehend the innovations, yet perhaps surprisingly it was within nature itself, within *biological life*, that mathematicians and the early computer theorists found a mode of complex processual thinking applicable to these emerging technologies.[6]

In 1934, Waddington stated that the conception of biology in terms of processes was recent: 'It is only within the very last few months that geneticists have begun to consider the gene itself as a process; instead of being content to regard it as a persisting chemical molecule, they have begun to take into consideration the reactions with its environment by which it is synthesised' ('Marxism and Biology', c. 1934, Waddington Papers). Only six years after the publication of Alfred North Whitehead's *Process and Reality* in 1929 — which according to Waddington had laid the foundation for his thinking — Waddington had begun to reconceive the field of biology in terms of organizational processes. However, the exact workings of this fluid relationship between an organism and its environment were not straightforward, as noted by biologist John Maynard Smith when he summarized Waddington's scientific achievements: '[His] observations reveal a "general evolutionary direction" towards more numerous and complex interactions between organism and environment' (Smith 1976: 120). Waddington's processual theories of the relationship, or organization, between an organism and its environment became a key source of inspiration for a wide field of systems thinkers. Indeed, as Mark Wigley describes, Buckminster Fuller, the renowned inventor, designer, and futurist, 'had followed [Waddington's books] closely since the late forties' (Wigley 2001: 100).

Topological Biopolitics

In his chair address at the 1966 International Seminar on Ekistics, Waddington defined his notion of 'biological organisation' as a system that

> carries out some functions in a way that is somewhat independent of the circumstances, and that it goes on carrying out this function more or less regardless of what is happening to it. If it responds to every minor pressure, the system is really too passive to be properly organised; on the other hand, a system which is quite independent of every external circumstance, and simply goes on doing the same thing without any relevance to anything else, would be too isolated and self-contained to be regarded as highly organised. Organisation therefore means to some degree, but not too great a degree, of independent ability to carrying out some function. (Waddington 1966: 2, ISE lectures, Doxiadis Archives)

Importantly, Waddington understood the complex organization between an organism and its environment as simultaneously both rigid and flexible: adequately autonomous to enjoy stability but adequately flexible to be able to change. In biological systems, organization could occur in two ways: first, as 'homeostatic organisation', which Waddington demonstrated to the Delos participants by the metaphor of self-regulating blood: if there is too much oxygen in the blood or the acidity is abnormal, the body will respond in ways which result in bringing the concentrations of these substances back to normal. 'Nearly all aspects of biological organisms exhibit some degree of similar homeostatic properties', he explained. 'The mechanism by which these homeostatic systems work goes under the fashionable name of "feedback"'. However, Waddington added that the idea of homeostasis and negative feedback 'are only the very first stage in arriving at a decent understanding of biological organisation'. Biological organisms had another fundamental quality, 'which is also, I am sure, fundamental in the ekistical systems which might be considered parallel to biological organisms. This property is that of changing in time' (Waddington 1966: 2, ISE lectures, Doxiadis Archives).[7] Waddington claimed an intimate parallel between ekistics and this understanding of biology because the sciences dealt with a mode of organization that changed as time passed: 'For this branch of biology there is again a good Greek word, "epigenetics". 'Waddington had coined the term 'epigenetics' in the 1930s, and he formalized its theory in the book *Organisers and Genes*, published in 1940. The Greek prefix 'epi-', meaning 'upon', 'on', or 'over', accentuated Waddington's theory: there was something *above* or *upon* our genome that had a significant effect on genetic heredity, which is that organisms can adapt to their developmental environment and can transfer this adaption to their descendants. 'This science', Waddington explained, 'deals with the interaction between the hereditary potentialities which organisms inherit from their parents and the surrounding circumstances in which they are growing up and developing' (Waddington 1966: 4, ISE lectures, Doxiadis Archives). Of significance is that Waddington's epigenetics did not consider the environment to be a three-dimensional entity alone, but was meaningful only in relation to the fourth dimension. This resonated perfectly with Doxiadis' own assertions that built settlements were not three-dimensional but four-dimensional — time-dependent — as well.[8]

Waddington's concept of epigenetics describes not a simple 'feedback' homeostatic property but a homeostatic *metamorphosis*, which he calls 'homeorhesis': a notion describing how constant change in biology is in fact connected to stability. 'Developing systems do not, of course', Waddington emphasized, 'preserve a stationary state, but they do have a tendency to preserve a definite pathway of change in time'. He asked the Delos participants to imagine an egg in its developmental phase as rolling down a mountainous hillside **(Figure 4)**. The egg can take several alternative paths, depending on the curves in the landscape. 'Now if in some way you push a developing biological system off its normal developmental pathway, it is most frequently observed that changes will occur which will tend to bring it back to the pathway at some later point', Waddington explained. 'Thus the pathway is in some sense stable — not in the sense that it does not involve changes in time, but in a sense that if the system is pushed off the path at one time it will tend to come back to the path a bit later on' (Waddington 1966: 4, ISE lectures, Doxiadis Archives). This sort of changing stability is what Waddington called homeorhesis, and the metaphorical curving hillside he called the 'epigenetic landscape'. Thus, his biological thinking is profoundly topological. The curves and thresholds in the landscape altered according to environmental conditions **(Figure 5)**, which guided the development of a cell, an egg, or an embryo along a necessary — but importantly also contingent — path. By crossing the threshold into another valley, mutations could be possible. What Waddington understood from his epigenetic viewpoint was similar to that of his 'twin' from a planning perspective: planning, building, and landscaping could evolve another future.

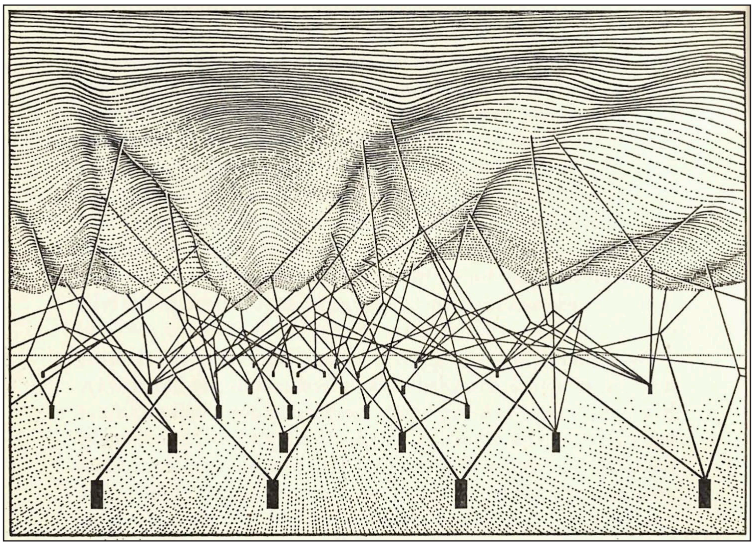

Figure 4: The complex system of interactions underlying the epigenetic landscape. From Waddington (1957: 36).

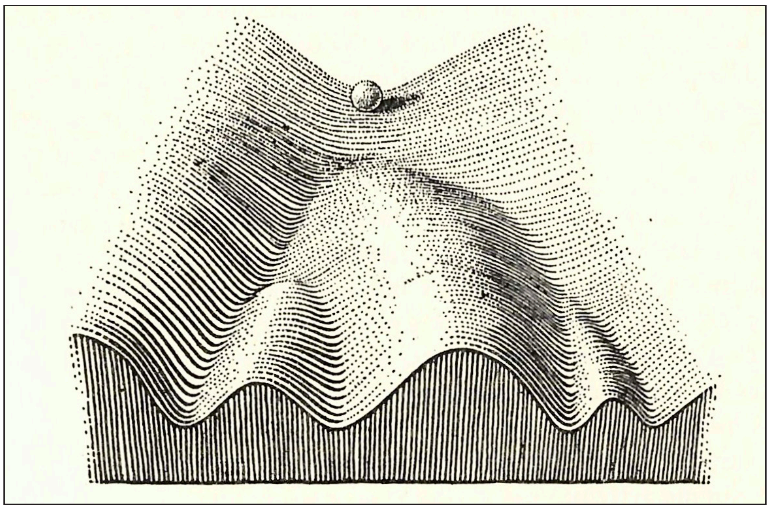

Figure 5: The epigenetic landscape. From Waddington (1957: 29).

From Cells to Cities?

'The city is the brain of society', said an anonymous commentator at Delos Four in 1966, 'the place of exploration of new ways' ('Urban Life: Its Values and the Problems It Faces' 1966: 245). In the discussions at this Delos gathering, the biological metaphors of the city intermingled almost feverishly with cybernetic theories, manifesting in the frequent use of terms such as interaction, network, organization, and feedback. Waddington points out, in his paper 'Biology and Human Environment' from the same year, that

> [biology and ekistics] are both dealing with people, animals, things, in intimate interrelations – influencing one another in a sort of networked world. The systems with which we deal are usually organized systems, in which everything is affecting everything else. But they are organized in rather more complicated ways than the ordinary feed-back relations which have become so fashionable in the physical world. (Waddington 1966a: 94)

Referring to the established dogma of cybernetics, Waddington claimed that 'such fashionable feedback-thinking' could not capture the complexity of the organization in an intimately networked world. In the Delos discussions, there was a new kind of cybernetic thinking surfacing that departed from previous systems thinking: Waddington's comment reveals that he understood his systems biology and Doxiadis' ekistic theory to belong to a second wave of systems thinking. Whereas the first generation of cybernetics provided a mode of thinking about closed systems, that is, feedback loops of inputs and outputs, so-called 'second-order' cybernetics understood the cybernetic mode of thinking as providing a theoretical framework for adaptive and responsive open-ended environments (a thorough study of neo-cybernetics is offered by Clarke 2014). In early cybernetics — and keeping in mind that the word comes from the Greek word 'κυβερνήτης' meaning 'the steersman, pilot or governor' — the system was in effect being over-steered. In Waddington's system biology, however, interrelations between people, environment, architecture, and cities — the system as such — were not only self-organized as a governing force in itself, but the interrelations also had a *regenerative* feed-back effect on the genome. As such, the gene, the biological self, was not something stable, but developed in correlation with the built environment.

Waddington's life-long observations on biological organization, which led to his formulation of epigenetics, clearly anticipated a second-order cybernetic. And in the conceptual landscape permeating the discursive debates at the Delos symposia, we clearly see a shift of attention from the discrete system that is to be observed — be it architectural, urban, social, economic, or infrastructural — to the system of which we and all the other systems are a reflexive part. Yet, importantly, these systems which we cannot fail to partake in are beyond anyone's control, as indeed Doxiadis affirmed in *Architecture in Transition*. Notions of hierarchy, agency, and control gradually dissolved (even though Doxiadis maintained some commitment to technocratic planning). Ultimately, however, the consequence of this second generation of systems thinking for urban theory was that 'the city has become a confused and complicated organism on which we look with fear. Some want to escape it, others remodel it, others to create it afresh' ('Urban Life: Its Values and the Problems it Faces' 1966: 244).

Waddington pointed out to the Delos participants that his theories held potential for urbanism and planning but translating the biological theory to real-life urban planning would be challenging:

> A town is an organised entity and has a definite organisation. You [the Delians] are attempting the extraordinary delicate task of creating organisms. Biologists have the simpler job of trying to analyse and understand them, but it seems to me not at all impossible that some of the concepts biologists have developed in attempting to understand organisms may be of interest to you in your more demanding task of developing them. (Waddington, 1966, ISE lectures, Doxiadis Archives)

Yet, at the Delos symposia in 1966, Waddington proposed how his theory of biological organization could develop into an urban theory. First of all, architecture needed to be re-conceptualized on a small scale. By handling relatively constant materials like 'bricks and mortar, and concrete and steel', Waddington worried that architects might not recognize they are dealing with 'something in process of change' (Waddington 1966a: 90). Rather, a building needs to be understood as dynamic, since the functions of a building need to change to respond to unknown challenges. In his lecture for the ISE, he said, 'I feel architects particularly … think they're dealing with something steady, but they're really dealing with something [in] process' (Waddington 1965, ISE lectures, Doxiadis Archives). Then architecture would have to be re-conceptualized at ever-larger scales. But Waddington acknowledged that this was more difficult, as

> neighbourhoods and towns don't suffer enough births and deaths for natural selection to cause their evolution. They tend to be built and modified, not built from scratch on a different pattern. When new towns are built, they are built on the experience of old towns. They are not really comparable to new mutation in biology. (Waddington 1971: 237)

On the scale of a city, the metaphor of biological organization could not easily transmute into an urban theory because a built city could not pass a sudden threshold (take a different 'path') and mutate into a new organism; in other words, a city could not easily take a new path. The city organism suffered from too much continuity, too much 'homeostasis', so that the system as a whole always responded in ways which brought abnormalities back to normal — a feedback loop. Accordingly, Waddington ended up criticizing the biological metaphors of the city that frequently circulated at the Delos symposia. The city could not be understood as a 'brain', as a 'nervous system', or as 'clustered cells'.[9] He chastised the Delos participants, saying, 'The nearest you can get to a biological image of a city is something not nearly as well defined as the structure of a human body, but something like the development of a sponge, which have four or five different cells that are somewhat separated from one another'. Perhaps a more promising biological metaphor was the bone, he proposed: 'To grow, a bone has to add bits on and take bits away. There is a very complex relation of additions to the new bone while the old bone is being taken away from the hollow inside. This is something one might consider as a possible means of modifying cities'. Waddington proposed that a city organized as an epigenetic system could be planned according to this bone model: 'if you want to enlarge the central area, you may have to add and remove simultaneously in a coordinated way' (Waddington 1971: 269).

The insight from systems biology was that designers needed to plan, build, and develop a city as solid structures in combination with a soft and flexible tissue, like a sponge or a bone. By being in a conceptual state of homeorhesis between solid structures and flexible tissue, a city could be understood as an epigenetic paradigm. However, Waddington's bone metaphor also reveals a key problem for developing epigenetics into an urban theory: if the built environment had a significant effect on the genome, how can the challenge of architectural determination be navigated? Would his epigenetic urban theory lead to city planning in the service of architectural biopower and governmentality? Again, the leftist biologist found an answer within his own discipline.

Waddington frequently stressed that 'nothing in biology is maximized' (Waddington 1968, 1963 Participant, Doxiadis Archives). At Delos Seven, he explained to the participants that 'the arrangement of biological groupings is a relation between its active components so that each of these components is optimized for the good of the grouping — the system — as a whole, and not maximized from the point of view of the individual components' (Waddington 1969a: 242). When Waddington transmuted his conception of biological organization — a system that is simultaneously stable and enduring yet flexible — into architecture, urbanism, and planning, he first envisioned an urban system that would serve the greatest good for the greatest number of people, not one that maximized profits for the few. He argued that the conceptual state of homeorhesis between solid structures and flexible tissue would allow for self-organization. In other words, a city understood as an epigenetic paradigm would enact agency not centrally, but to distribute power, to local bodies:

> Ridiculous (from a world point of view) central areas of super-rich American cities (Chicago, Washington, Newark), where unemployed workers, mainly black, live in sub-standard accommodation which their own labour, if it could be released from the straight-jacket of our economic system, would be able to transform into an environment which they would enjoy and be proud of. (Waddington 1971, Participant 1963, Doxiadis Archives)

According to Waddington, a city needed to be planned not as a cybernetic program, because '[d]esigners', Waddington explained in his Delos lecture in 1965, 'can't really tell what [they] are designing for' (Waddington 1965, ISE lectures, Doxiadis Archives). A city as an epigenetic organism, on the other hand, would be an open-ended feedback system in which accidents, revolutions, or catastrophes could disrupt the status quo and allow mutations. Waddington summarized his proposition as follows:

> As a final word I would like to say that what the biological system has to do, is to meet unforeseeable challenges. Animals change by a mutation of their heredity factors, but they don't know whether the world is going to slip in an ice-age on them, or some horrible new virus is going to come along and either kill them or kill off their food supply. They are playing a game of chance and any sort of system has to take this feature into account. You cannot really tell what you are designing for, but you have got to be able to design something which is sufficiently flexible and resistant to change and catastrophe to be able to make a quite a good job of it, even if the world does not turn out as you thought it was going to. (Waddington 1966a: 94)

Such an epigenetic conception of a city, Waddington said in a keynote address at the International Seminar of Ekistics in 1966, indicated a 'plan [which has] full potentialities for dealing with a whole lot of situations which it may be confronted with and a future which can only be foreseen in a very rough and incomplete way' (Waddington 1966, ISE lectures, Doxiadis Archives). Yet how might such a system be planned? Waddington teased the Delians with the question, before offering up his tantalizing answer, or at least, a tantalizing way to begin to think through the problem: 'What the conscious designer has got to do is to find some way of building this in, consciously' (Waddington 1966a: 94).

Yet Waddington's urban epigenetics did not have the influence he had hoped for, as it was the homeostatic logic of the economic system that ensured the survival of the status quo. The logic, driven by economics, was too resilient, and founded on those mechanisms of maximized growth that Waddington had disparaged. In preparation for the tenth Delos symposium in 1972, Waddington wrote to Doxiadis about the topics he wished could be addressed during the coming cruise in the Mediterranean: 'One of the major problems is how to combine rapid growth and capital investment in major human requirements, such as urbanisation and settlements in the next few decades with restraints in investment and production' (Waddington 1971, Participant 1963, Doxiadis Archives). This concern had, nevertheless, grown out of a disciplinary insight; knowing that nothing in biology was maximized, Waddington reflected back on the implications of the Delos endeavours in November 1971:

> We started Delos with enormous emphasis on the vast amount of housing or settlement building that was needed and one of the great services of Delos was that it was the first body of thought that came out and made an impact on the public in pointing out the magnitude of the task of providing shelter. Delos has always had a background of talking about growth, but at the present time there are very strong movements in many advanced countries for a slower population increase and for a no-growth economy. ... Although Delos started with emphasis on growth it has really led to a discussion of standards on the quality of living which would be appropriate to a zero growth economy ('World Society' 1971, Waddington Papers).

The two men standing beside each other and staring at the ludo symbol in ancient Didyma were in some ways each other's twin. Even the seemingly different ideological positions between a leftist biologist and a 'technocrat for development' (see Pyla 2009) were not that different from each other. The biologist and the architect agreed that they were fundamentally uncertain about how to understand the world's accelerating complexities. The two men were also using the same terminology to reach similar conclusions: they championed the conceptual notions of de-centredness and open-endedness as ideological — and epistemological — tools to confront totalitarian modernism (these ideological nuances are discussed in Halland 2024). Both also claimed that notions of localized power and decentralized autonomy were necessities to tackle inevitable problems to come, and that planning was a key component in building a better future for the greater good of the world's population. But throughout his life, Doxiadis maintained his belief in his dynamic, holistic planning theory, in which the notion of open-endedness remained an ekistical status quo. For Waddington, on the other hand, a change in his interdisciplinary thinking can be detected in his later years.

Seeming almost regretful of the early Delian utopian ideology when set against deeply entrenched assumptions of the city as a mechanism for growing capital, Waddington ventured into a new field in the final years of his life. From the late 1960s onward, the leftist biologist turned his attention from epigenetic theories for hands-on building and planning toward more purely philosophical explorations of aesthetics and epistemology. His biological theory thus became even more interdisciplinary.

Toward an Epigenetic Epistemology

In the late 1960s, Waddington's epigenetic biology thus transmuted into a transdisciplinary epistemological theory, which had multi-level implications in the thriving field of transdisciplinary research initiatives. In 1968 he was invited by the Italian industrialist Aurelio Peccei, the president of Olivetti, to join the initial meeting of what would later become known as the Club of Rome.[10] The Delos Symposion and the Club of Rome had several overlapping members, and the two initiatives shared methodological means and political aims (the aim of the initial Club of Rome meeting was to identify the most pressing problems of the world and then suggest solutions for how to tackle the forthcoming challenges).[11] Waddington's transdisciplinary epigenetics moved further away from hands-on building and planning in the late 1960s when through the Club of Rome he met Erich Jantsch, an astrophysicist and engineer who Larry Busbea describes as a 'system theorist and management guru'.[12] The two began a collaboration that would be published in the book *Evolution and Consciousness: Human Systems in Transition* in 1976. In this book, Jantsch continued his long-standing idiosyncratic usage of the term 'design' to mean a problem-solving method for human self-development, in opposition to the modernist paradigm of 'planning'. Waddington and Jantsch claimed that epigenetic design would transform the human subject from a modernist subject — aiming for perfection — to a self-transcendent subject with environmental awareness in tune with a changing and complex environment: 'Human design, undertaking to align with evolutionary emergence ... will reverse many courses of action prescribed by contemporary planning and stabilization paradigms'. Drawing on Whitehead's process philosophy and deeply influenced by Eastern philosophies, Jantsch and Waddington concluded that certainty had come to an end: 'Evolutionary process implies openness self-transcendence and thus imperfection, courage, and uncertainty — not the deterministic perfection, static security, and certainty inherent in the ideals of the traditional structure-oriented western world-view' (Jantsch and Waddington 1976: 7).

In 1968, Waddington enthusiastically wrote to Doxiadis with news that his latest book had finally been published. In *Behind Appearance*, a strikingly visual publication, Waddington investigates the interrelation between the development of modern painting and science. Doxiadis replied that Waddington's book on art and science was 'one of the best bridges I have seen connecting fields of human knowledge and experience which were considered completely separate one generation ago'. Doxiadis ended his letter with a phrase that implies his reason for considering Waddington his 'twin':: Waddington's book 'open[s] doors so that we can gradually achieve much that we did in the past when we were living in our separate world compounds of disciplines' (Doxiadis to Waddington 1970, Participant 1963, Doxiadis Archives). For Waddington, *interdisciplinarity* survived the mutation in his thinking, and remained a constant stimulus for regeneration.

In the conclusion of *Behind Appearance*, titled 'The Profits of Plurality', Waddington summarizes the implications of an epigenetic cultural theory:

> (a) The epistemological foundation. The observer does not wholly make what he observes .... There is no strict objective-subjective dichotomy. The painter is *in* his painting. The scientist is *in* his science. (b) Change plays a role amongst the fundamental mechanisms. (c) Everything 'has a feeling for' (prehends) everything else; things have fuzzy edges. (d) On a more down-to-earth-level: we live in surroundings and conditions that we ourselves make, not in any state of nature that we have to accept in its entirety. (Waddington 1969: 240)

In this paragraph, we clearly see that Waddington's epistemic epigenetics was preemptive of contemporary interdisciplinary issues in the humanities.

At the Delos Symposion, a conceptual genealogy from systems biology and second-order cybernetic modes of thinking was cultivated, leading to today's methodological approaches in the humanities that aim to destabilize subjectivity and objectivity as epistemological notions, especially when conceived as dualities, such as culture versus nature, mind versus body, subject versus object. The eco-feminist philosopher Donna Haraway is today perhaps the most celebrated theorist within contemporary humanities who advocates conceptual notions such as pluralism (which she calls 'tentacular thinking') and objective-subjective fluidity. When Haraway completed her PhD in the department of biology at Yale in 1972 on the topic of organicist paradigms in biology, focusing on the Theoretical Biology Club of which Waddington was a central member, Waddington functioned as a key source for her argument.[13] Haraway's thesis was published in 1976 as the book *Crystals, Fabrics, and Fields: Metaphors that Shape Embryos*, and insights from Waddington's systems biology has followed Haraway's thinking ever since. Thus, the contemporary epistemological landscape pioneered by Haraway is undoubtedly tied to, and to some degree fuelled by, the questions explored by the interdisciplinary group at the Delos symposia five decades ago.

Conclusion

In post-war Western theory and critique in general, and in architecture, philosophy, and social theory in particular, universalist notions of stability, essence, and structure were challenged by notions of open-endedness, feedback, and dynamic interactions. Consequently, 'environment' came to be an emblematic interdisciplinary trope for the 1960s: in architecture, urbanism, and social theory, the environment lost its status as an independent and stable entity that surrounded the subject (or object) and came instead to be recognized as a relational floating structure between subjects, objects, communication, languages, and signs. Waddington emphasized all of these by describing how 'people, animals, things, in intimate interrelations — influenc[e] one another in a sort of networked world' (Waddington 1966a: 94).

Waddington's encounter with Doxiadis' ekistics reveals a unique interdisciplinary attempt to connect architectural purpose and ethical epistemology. Yet the 'twins' were not identical. Although Waddington's biology laid critical foundations for systems biology, thereby clearing the ground for the emerging 'network epistemology', his interdisciplinary epigenetic epistemology still radically differs from conventional network epistemologies that crystalized with Buckminster Fuller and Marshall McLuhan — and to some extent continues into present-day humanities, such as Haraway's eco-feminism. While originating from the common genetic factor (cybernetic thinking), the conceptual and disciplinary parallels between ekistic theory and epigenetic theory differed in the theoretical and ideological understanding of systems. Waddington's epigenetic system was not a continuous loop of open-endedness, like Doxiadis' city system that was made up of continuous centres and growing toward a planetary city which he called 'ecumenopolis'. In addition, Waddington became convinced that the current crisis could not be confronted by means of planning and governmentality. The biologist looked beyond current systems — beyond cities and cells — to push these systems off their normal developmental pathways, hoping that future ethical and epistemological mutations would restrict unbridled growth and allow for creative regeneration.

Notes

[1] Didyma is one of the sites investigated in the European Research Council's Advanced Grant research project 'Locus Ludi: The Cultural Fabric of Play and Games in Classical Antiquity' (2017–2022).

[2] The organizers used the Ancient Greek form *symposion* for symposium in the plural.

[3] The final two Delos Symposion, held in 1974 and 1975, took place at the Athens Center of Ekistics and the Apollonion settlement in Porto Rafti, Greece.

[4] Waddington is described by Mckenzie Wark as scientific socialist and by Erik L. Peterson as a leftist biologist with strong ideological tendencies in the direction of Marxism (see Galloway 2017; Peterson 2010).

[5] 'Blanco White, Margaret Justin 1911–2001' in AHRnet, Available online at: https://architecture.arthistoryresearch.net/architects/blanco-white-margaret-justin [last accessed 25 September 2024].

[6] Systems biology and cybernetic theories of early computers simultaneously informed and reformed the other, culminating in cybernetic visionaries who envisioned the computer as an animate inanimate, quasi-human thing, as Buckminster Fuller described in one of his lectures at Delos: 'The human mind invented the computer as an extension of humanity's integral computer, information storing and retrieving system, the brain' (Buckminster Fuller 1969: 290). At the Delos symposia in 1966, Kenzo Tange established that in the Second Industrial Revolution (which he held to be characterized by 'information theory and communication techniques'), computers would work as 'manmade brains [that] absorb millions of bits of information, remember them, arrange them, compile them' ('Need For More Balance in the Flow of Communications' 1966: 275).

[7] Already in 1964, Waddington wrote enthusiastically about ekistics in the article 'Science and Wisdom', published in *New Scientist* (Waddington 1964) (a copy is in the Doxiadis Archive, folder 6828).

[8] The development of ekistics was informed by developments in cybernetics and general systems theory as discussed in Tywitt and Bell (1972); see also Tsiambaos (2018).

[9] Referencing Norbert Wiener, Kenzo Tange, for instance, defined the present-day urban system as 'informational couplings' in contrast to 'energetic couplings'. Comparing energetic couplings with ancient society, Tange gave the analogy that the connections in this system was 'perhaps like the links between cells in a plant'. An informational coupling, on the other hand, 'is the sort of connection that links together the cells of an animal. It involves a nervous system along which information is sent and returned in order to control action. In other words, it is a link that requires the possibility of mutual exchange or feed-back' ('Need For More Balance in the Flow of Communications' 1966: 275).

[10] Letter from Aurelio Peccei to Waddington, 9 February 1968 (Waddington Papers). Waddington became a founding member of the Club of Rome from its inception 1968, and he remained involved until his death in 1975.

[11] The environmental movement owes much of its legacy to the Club of Rome's publication of the 1972 book *The Limits to Growth*. The book has been claimed to be the most successful publication in the field of environmental studies, mainly due to the book's wide-ranging influence, selling 12 million copies in more than 30 languages. The argument of the book was that five factors – pollution, population, agricultural production, natural recourses, and industrial production – were fully entangled and dependent on each other, so no single action addressing one, or two, of the factors would have any effect on the whole (corresponding to the argumentation of Doxiadis). According to the authors of *Limits to Growth*, exponential economic growth – and population growth – would empty the natural resources, and even if new renewable resources were discovered (or invented) this would already be too late; the collapse would already have happened through pollution. For a brief account of the history of the Club of Rome, see the book's foreword (Meadows et al. 1972: 9–12).

[12] Erich Jantsch, another founding member of the Club of Rome, had penned the initial working document describing the Club of Rome's aims, means, and methodology: *The Predicament of Mankind: Quest for Structured Responses to Growing World-Wide Complexities and Uncertainties.* Jantsch is referenced several times in Larry Busbea's *The Responsive Environment* as a figure contributing to an epistemological reconceptualization of the environment in the field of architecture and design in the 1970s (Busbea 2020).

[13] Waddington is thanked in the acknowledgments of the published version of Haraway's PhD thesis (Haraway 1976).

Acknowledgements

I would like to express my deep gratitude to Simon Richards and Mantha Zarmakoupi for inviting me to speak at the symposium 'The Delos Network: Delos Now' at Loughborough University, UK, in

2019, where a first draft of this article was presented. I am also thankful for the assistance provided by the archivists at the Edinburgh University Library Special Collections Repository, Scotland, and at the Doxiadis Archives, Benaki Museum — Pireos St. Annexe, Athens, Greece. The article has been significantly enhanced through the comments, suggestions, and feedback from Richards and Zarmakoupi, Panagiotis Farantatos, as well as the anonymous peer reviewers and Samantha Martin, Manuel Sánchez García, and Lenore Hietkamp of *Architectural Histories*. Any remaining errors or lack of clarity are solely my own.

Competing interests

The author has no competing interests to declare.

References

Unpublished Sources

Waddington Papers. Papers of Conrad Hal Waddington, Edinburgh University Library Special Collections Repository, Scotland. https://library.ed.ac.uk/discovery/special-collections-museums

'Marxism and Biology' c. 1934 (undated). Two typescript drafts of the same name. Coll-41/2/1/4.

World Society of Ekistics and British Delians Meeting, London, UK, 24 September 1971. Transcription. Material relating to the Delos Symposia and various ekistics-related organisations, 1963–1975, Coll-41/6/7.

Doxiadis Archives. Constantinos A. Doxiadis Archives, Benaki Museum, Athens, Greece.

Conrad Hal Waddington to Constantinos Doxiadis. 1971. 'Delos 10'. Short note. Folder 6828, Participant 1963 Waddington.

Constantinos Doxiadis to Conrad Hal Waddington, 1970. 13 January. C-DA 7899. Folder 6828, Participant 1963 Waddington.

Waddington, CH. 1965. 'Biology and Human Environments', 23 July. Transcribed ISE lecture. Folder 8141, ISE lectures.

Waddington, CH. 1966. 'Progressive Self-Stabilization Systems in Biology and Social Affairs'. Chair address at day 5 of the 1966 International Seminar on Ekistics. Folder 8141, ISE lectures.

Waddington, CH. 1968. 'The Relevance of Biological Types of Thought', November. Folder 6828, Participant 1963 Waddington.

Published Sources

Ashby, WR. 1956. *An Introduction to Cybernetics*. London: Chapman & Hall.

Blakinger, JR. 2019. *Gyorgy Kepes: Undreaming the Bauhaus. Illustrated edition*. Cambridge, Mass.: The MIT Press.

Buckminster Fuller, R. 1969. The World Game. *Ekistics*, 28(167): 286–292.

Busbea, L. 2017. Soft Control Material: Environment and Design c. 1970. *Journal of Design History*, 30(2): 139–156.

Busbea, L. 2020. *The Responsive Environment: Design, Aesthetics, and the Human in the 1970s*. Minneapolis: University of Minnesota Press.

Clarke, B. 2014. *Neocybernetics and Narrative*. Minneapolis: University of Minnesota Press.

Doxiadis, C. 1960. Dynapolis, the City of the Future. Lecture at the Oslo Arkitektforening, Oslo, March 3. Published in Document R-GA vol. 185. Athens: Doxiadis Associates.

Doxiadis, CA. 1963. *Architecture in Transition*. London: Hutchinson.

Doxiadis, CA. 1968. *Ekistics: An Introduction to the Science of Human Settlements*. London: Hutchinson.

Dutta, A (ed.). 2013. *A Second Modernism: MIT, Architecture, and the 'Techno-Social' Moment*. Cambridge, Mass.: SA+P Press & MIT Press.

Farantatos, P. 2022. Plastic Leisure for All: The Hexacube and the Seaside Development of Leucate-Barcarès. In: Bozdoğan, S., Pyla, P., and Phokaides, P. (eds.), *Coastal Architectures and Politics of Tourism: Leisurescapes in the Global Sunbelt*. London: Routledge.

Galloway, AR. 2017. An Interview with McKenzie Wark. *b2o*, the online community of *boundary 2* editorial collective. 17 April. Online at https://www.boundary2.org/2017/04/alexander-r-galloway-an-interview-with-mckenzie-wark/ [last accessed 25 September 2024].

Halland, I. 2020. The Unstable Object: Glifo, Blow, and Sacco at MoMA, 1972. *Journal of Design History*, 33(4): 329–345.

Halland, I. 2024. Seeds for New Beginnings? Ecological Uncertainty, Blurry Ideology, and Speculative Design at the Universitas Symposium, 1972. *Journal of Design History*, 37(1): 70–85.

Halpern, O. 2014. *Beautiful Data: A History of Vision and Reason since 1945*. Durham: Duke University Press.

Haraway, D. 1975. The Transformation of the Left in Science: Radical Associations in Britain in the 30's and the U.S.A. in the 60's. *Soundings: An Interdisciplinary Journal*, 58(4): 441–462.

Haraway, D. 1976. *Crystals, Fabrics, and Fields: Metaphors that Shape Embryos*. Berkley: North Atlantic Books.

Hayles, NK. 1999. *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago: University of Chicago Press.

Hight, C. 2007. *Architectural Principles in the Age of Cybernetics*. New York: Routledge.

Jantsch, EE, and Waddington, CH (eds.). 1976. *Evolution and Consciousness: Human Systems in Transition*. Reading, MA: Addison-Wesley.

Mead, M, et al. 1963. Contributory Papers. *Ekistics*, 16(95): 254–262.

Meadows, DH, Meadows, DL, Randers, J, and Behrens, W, III. 1972. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. London: Earth Island Ltd.

Meeting in Delos: An Interview with Sir Robert Matthew. 1963. *The Architect's Journal*, 21 August: 362.

Need for More Balance in the Flow of Communications. 1966. *Ekistics*, 22(131): 273–285.

Peterson, EL. 2010. Finding Mind, Form, Organism, and Person in a Reductionist Age: The Challenge of Gregory Bateson and C. H. Waddington to Biological and Anthropological Orthodoxy, 1924–1980. Unpublished thesis (PhD), University of Notre Dame.

Pyla, P. 2002. Ekistics, Architecture and Environmental Politics, 1945–1976: A Prehistory of Sustainable Development. Unpublished thesis (PhD), Massachusetts Institute of Technology, Dept. of Architecture.

Pyla, P. 2009. Planetary Home and Garden: Ekistics and Environmental-Developmental Politics. *Grey Room*, 36: 6–35.

Sadler, S. 2016. The Bateson Building, Sacramento, California, 1977–81, and the Design of a New Age State. *Journal of the Society of Architectural Historians* 75(4): 469–489.

Scott, FD. 2016. *Outlaw Territories: Environments of Insecurity/Architectures of Counterinsurgency*. New York: Zone Books.

Smith, JM. 1976. Ethics and Human Evolution, *New Scientist*, 70 (15 April): 120–123. http://hdl.handle.net/10822/773784

Steenson, MW. 2017. *Architectural Intelligence: How Designers and Architects Created the Digital Landscape*. Cambridge, Mass.: MIT Press.

Theodosis, L. 2015. *Victory over Chaos? Constantinos A. Doxiadis and Ekistics 1945–1975*. PhD thesis. Departament de Composició Arquitectònica, Escola Tècnica Superior d'Arquitectura de Barcelona, Universitat Politècnica de Catalunya.

Tsiambaos, K. 2018. *From Doxiadis' Theory to Pikionis' Work: Reflections of Antiquity in Modern Architecture*. London & New York: Routledge.

Ulak, A. 2023. Diagrammatic Abstractions: Jay Forrester's Urban Dynamics and Its Contribution to Architecture and Urban Planning in the Late 1960s and Early 1970s. *Architectural Histories* 11(1). DOI: https://doi.org/10.16995/ah.8284

Urban Life: Its Values and the Problems It Faces. 1966. *Ekistics*, 22(131): 244–253.

Waddington, CH. 1947. *Organisers and Genes*. Cambridge: Cambridge University Press.

Waddington, CH. 1957. *The Strategy of the Genes*. London: Allen and Unwin.

Waddington, CH. 1964. Science and Wisdom. *New Scientist*, 384(26 March): 807–808.

Waddington, CH. 1966. Biology and Human Environment. *Ekistics*, 21(123): 90–94.

Waddington, CH. 1969. Biological and Phycological Considerations of Groupings. *Ekistics*, 28(167): 141–143.

Waddington, CH. 1969. *Behind Appearance: A Study of the Relations between Painting and the Natural Sciences in This Century*. Edinburgh: Edinburgh University Press.

Waddington, CH. 1971. Space for Development. *Ekistics*, 32(191): 168–169.

Wiener, N. 1948. *Cybernetics: Or Control and Communication in the Animal and the Machine*. Cambridge, Mass.: Technology Press.

Wigley, M. 2015. *Buckminster Fuller Inc: Architecture in the Age of Radio*. Zürich: Lars Müller Publishers.

Wigley, M. 2001. Network Fever. *Grey Room*, 4: 82–122.