

**Architecture Theory 1960-1980 . Emergence of a Computational Perspective**

by

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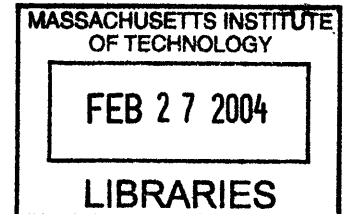
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## **Abstract**

This thesis attempts to clarify the need for an appreciation of architecture theory within a computational architectural domain. It reveals and reflects upon some of the cultural, historical and technological contexts that influenced the emergence of a computational practice in architecture.

To carry out this new reading, we focus on the pioneering research that underpinned the beginnings of the relationship between architecture and computation and which was carried out at four research Centres both in the UK and in the USA: The Land Use and Built Form Studies [LUBFS], founded at Cambridge, UK; The Center for Configurational Studies at the Open University, Milton Keynes; The Architecture Machine Group [AMG] at MIT, and the Design Research Center [DRC] at Carnegie Mellon University, Pittsburgh, USA.

Moreover this thesis reinterprets the role of Leslie Martin as the founding father of LUBFS by showing the influence of the British physicist Desmond Bernal's building science research and the British avant-garde movement on Martin's work.

This thesis also presents reflections on how best to use computation in architecture.

Thesis Supervisor: William J. Mitchell  
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*The only journey is within*

Rilke



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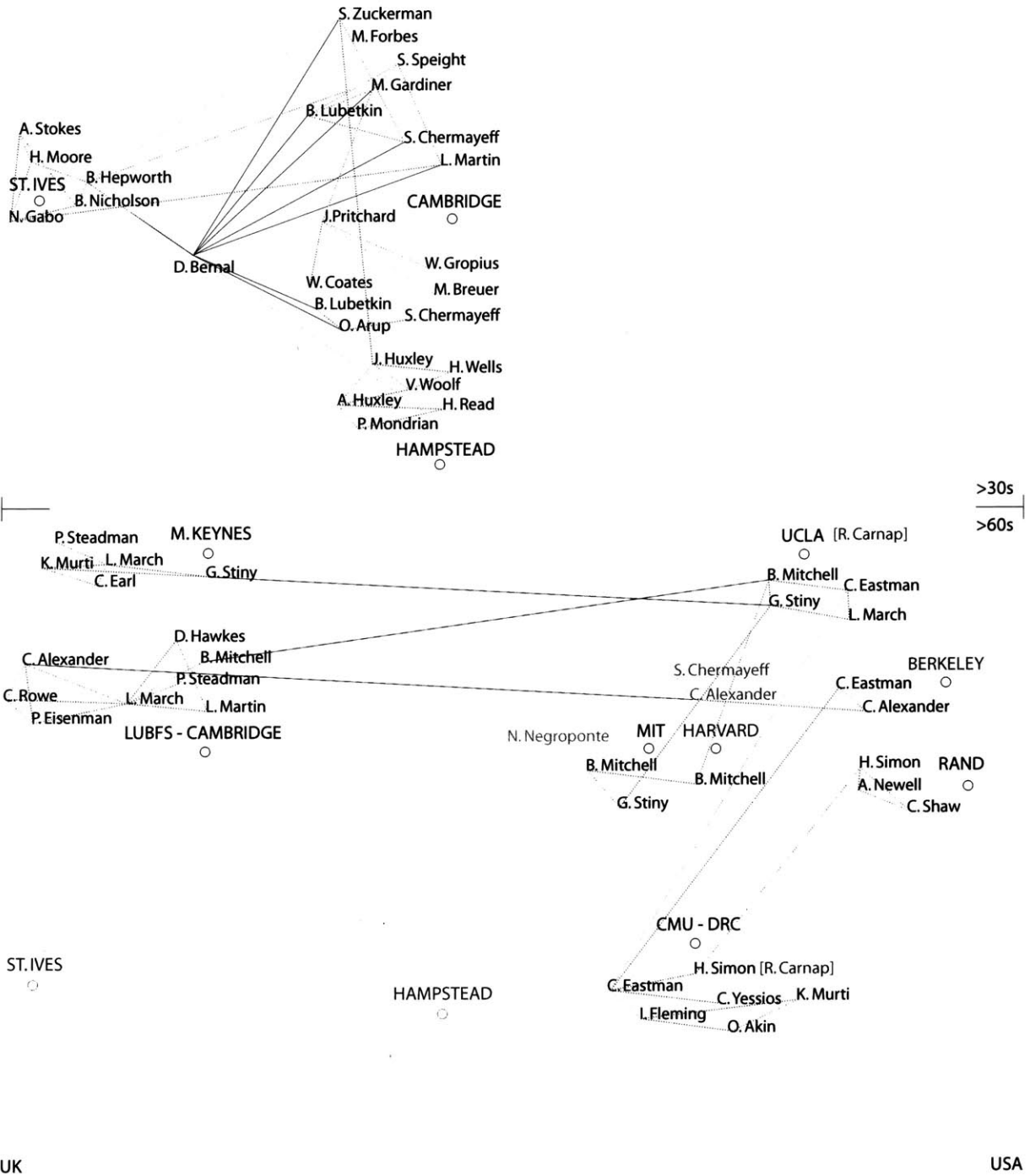


Fig 00.



CHAPTER 1 Introduction

## 1.1 Introductory note

This research attempts to outline a context for an architectural practice that does not fully exist, and seeks cohesion to a hitherto fragmented perspective of history. In this respect it finds parallels with Paul Klee's *Angelus Novus*,<sup>1</sup> an allegorical Angel that faces towards the future. Regarding this image, the philosopher Walter Benjamin wrote:

An angel who looks as if we were about to take leave of something at which he is staring. His eyes are widened, his mouth is open, and his wings are extended. This is what the Angel of History must look like. He has turned his face toward the past. Where a chain of events appears before *us*, there *he* sees a single catastrophe, which ceaselessly piles rubble on top of rubble, tossing it before his feet. He would like to remain, to awaken the dead, and to join again what has been smashed. But from the direction of Paradise there blows a storm, which has caught his wings and is so strong that the angel is no longer able to close them. This storm drives him irresistibly into the future, to which his back is turned, while the pile of rubble before him grows up to heaven. This storm is what we call progress.<sup>2</sup>

## 1.2 Objectives

This work reflects on the role that architecture theory has to play within a computational, architectural culture and practice. The lack of a plural view of the recent history of architecture in the field of computation compelled us to draw up a map of some artistic and cultural events that start to took place during the 30s in the UK. These intellectual phenomena were seminal to promote a culture of scientific research, which would be enhanced along the 50s and 60s. To this end, this thesis focus on the work carried out at five research centers both in the UK and in the USA: The Land Use and Built Form Studies [LUBFS], founded at Cambridge, UK, by Leslie Martin in 1967, The Institute for Architecture and Urban Studies in New York [IAUS], founded in 1967 by Peter Eisenman; The Center for Configurational Studies at the Open University, Milton Keynes, UK, established by Lionel March in 1971; The Architecture Machine Group [AMG] at MIT, established by Nicholas Negroponte, also in 1967, and the Design Research Center [DRC] at Carnegie Mellon University, Pittsburgh, USA, launched in 1975 by Herbert Simon. The aim is that by constructing this broader context, on the one hand we will narrow the gap between the recent history of architecture with the appliance of theory of computation within architecture and, on

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<sup>1</sup> *Angelus Novus* an aquarelle painted by Paul Klee.

<sup>2</sup> Benjamin, W. [1940]. "Theses on the Philosophy of History," *Illuminations*. Edited by Hannah Arendt. New York: Harcourt, 259-60. Benjamin acquired this aquarelle to Paul Klee in mid 20s.

the other hand, we will be better able to acknowledge a historical realm that influenced the formation of our contemporary architectonic computational culture [Fig. 00].

The goal of this thesis is also to reflect on how best to use computation in architecture. The dawn of computation introduced major changes in the relationship between theory and practice; a correlation between 'software' and architectural processes which was increased but, at the same time, become more faint as we enter a diverse domain of rules creation, of constraints and variables definition, of form emergence, and of architectural criteria as well. The increased creative capabilities that new computational processes allow are vast, and so they should be included in a larger theoretical frame of reference. This leads to the suggestion that the proper conception and design of 'software'<sup>3</sup> becomes part of the design process and of theory development.

Finally this work deals with historical matters, but does not pretend to present a linear perspective of it. It draws mainly on Walter Benjamin's concept that the hidden paths between historical moments also construct history, and from Michel Foucault's notion of "archaeology" and of transformations that serve as new foundations. As Foucault points out, an analysis of discontinuous discourse does not belong to the traditional history of ideas or of science: "it is rather an enquiry whose aim is to rediscover on what basis knowledge and theory became possible; within what space of order knowledge is constituted. Such an enterprise is not so much a history, in the traditional meaning of the word, as "archaeology." <sup>4</sup> The following pages present the archaeology of our field of investigation.

### 1.3 Thesis outline

The structure of the thesis should be read as the rhizomatic interplay of seven chapters. Chapter Two focuses on the present state of architecture theory, and highlights an interpretation of literature review in this domain. Our approach to theory is built on some ideas of "critical theory", and on the concept of "modeling". Chapter Three gives emphasis to the origins of the relation between computation and architecture. This subject is analysed through a comparative reading of different intellectual phenomena that influenced the practice of architecture in the early 60s, structuralism being one of the major driving forces in

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<sup>3</sup> In this work the term 'software, unless otherwise noted, should be read as a computational Generative System.

the “quantitative revolution”. Chapter Four focuses on the UK context, particularly on the emergence of the British Avant-garde as a cultural phenomenon that nurtured the discussion about the relationships between art and science. Moreover, the “constructivist” environment that was brought by many of the Russian artists who left their country after the 1917 revolution, the fusing of scientific and artistic ideas that were in vogue in London and Cambridge in the 30s, and the flight from Germany of many of the Bauhaus leaders, favored a unique intellectual environment for the emergence of modernism and of a new research agenda for architecture. The hypothesis put forward is that Leslie Martin’s idea for the foundation of LUBFS had its roots in this intellectual milieu of the 30s. Chapter Five focuses on the important role played by the Cambridge physicist John Desmond Bernal, who was one of the key persons to ignite the cultural and scientific discussion of that period in the UK, and who first brought architecture into the field of applied research. This chapter also addresses the question of WWII as a major event that had such influence on the gathering of different architects and scientists addressing various research problems related to the war. Moreover it considers the research conducted at LUBFS, how it pioneered the emergence of many ideas regarding the relation between architecture and computation and how this venture supported a migration of research from the UK to the US. Chapter Six pays tribute to the computational ideas developed in the USA particularly by the work carried out by Herbert Simon at the RAND Corporation, and at same time, illustrates the beginning of the debate on the role of computers in architecture that took place by the mid 60s.

The final chapter attempts a conclusion and indicates further work, and the Appendix highlights [some] current work in the domain of generative systems and point up the theoretical principles through which these models of computation operate. Furthermore it speculates on how the merging of theory with certain models of computation could take place.

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<sup>4</sup> Foucault, M. [1970]. *The Order of Things: An Archaeology of the Human Sciences*. New York: Vintage Books, xxi-xxii.

## CHAPTER 2 Theory

## 2.1 The advent of contemporary theory

Diverse attitudes towards architecture theory led to the production of a wealth of literature on the subject. On the one hand, there is literature that reviews theory from the “critical theory”<sup>5</sup> point of view, and on the other hand, literature that unveils the field of architecture theory, seen from a ‘scientific’ standpoint. This illustrates the dichotomy in which architecture theory has been placed and how much of the present schism existing between theory and practice is due to the drift between these two poles.

The advent of the debate on the role that architecture theory has to play within a ‘contemporary’ architectonic context appeared at two major conferences<sup>6</sup>: first, the ‘Conference on Architectural Education’ held at Magdalen College, Oxford, in 1958, and second, ‘Practice, Theory and Politics in Architecture’, a conference held at Princeton University, in 1974. The sixteen-year period between the two events clearly highlights the difference in scope that both meetings addressed: the former with a specific educational theme, the latter focusing on ‘ideological’ issues. Despite these dissimilarities, both meetings promoted reflection upon the importance of architectural theory. Leslie Martin’s speech at the Oxford meeting became a point of reference as he stressed the need of an existing body of theory through which architectural ideas could emerge. Martin pointed out: “Knowledge will be guided and developed by principles: that is, by theory. Research is the tool by which theory is advanced. Without it, teaching can have no direction and thought no cutting edge.”<sup>7</sup> In ‘Practice, Theory and Politics in Architecture’ the presentation of the Italian historian Manfredo Tafuri pointed to the end of the modern project in the face of the everlasting power of capitalism. Tafuri placed architecture in a wider range of influences, understanding architectural phenomena through its hidden forces of social and bourgeois culture. A Marxist reading that formed a new critical medium to explain the relations between culture, social values and the production of architecture.<sup>8</sup>

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<sup>5</sup> “Critical theory,” a term coined by the Frankfurt School of Social Research, meaning a particular critique of social phenomena.

<sup>6</sup> Michael Hays refers the second conference as the birthing place of contemporary theory. See, Hays, M. [1998]. *Architecture Theory since 1968*. [edited by K. M. Hays]. Cambridge, Mass: The MIT Press.

<sup>7</sup> Martin, L. [1958, June]. “Conference on Architectural Education,” *RIBA Journal*, 65 [8], 280.

<sup>8</sup> “Per una critica dell’ideologia architettonica.” Tafuri would later expand this argument in his “architecture dans le boudoir.”

This division was recently discussed by architects, historians and philosophers, who analyzed the inner isolation of a theoretical activity, which is frequently the preserve of autonomous groups of intellectuals who do not successfully relate their theoretical positions to the daily debates on current architectural practice.<sup>9</sup> The historian and architectural theorist Michael Hays says that the claimed “lament about the split between theory and practice” is featured as a “transactional” period due to changes in the order of a cultural environment that faces increased economic and technological developments.<sup>10</sup> The question, “has theory, hermeticism, and un-self-critical attitude contributed to its failure to engage effectively in the practical arena?”<sup>11</sup> reflects an awareness which implies an inquiry into the way in which architecture is perceived today, and also suggests the need to revisit theory’s own history.

As Michael Hays pointed out, theory acts as an intellectual mediator between architecture and other external influences and codes, playing the role of establishing systems that make possible the incorporation and decoding of external codes or ideas into meaningful architectural contexts. Theory, which may or may not be explicitly involved in the formulation of these initial creative premises, is, however, necessary for the understanding of the meaning of newly formulated concepts. Far more important, theory will be necessary in order to allow the conceptual development and critical manipulation of these notions. This brings to mind the words of the literary critic Terry Eagleton. He observes, “Theory is just a human activity bending back upon itself, constrained into a new kind of self-reflexivity; and in absorbing this self-reflexivity, the activity itself will be transformed, as the production of literature is altered by the existence of literary criticism.”<sup>12</sup>

As in literature, or in any other art form, architecture, before being formulated, is a relation of thoughts that, at a given moment establish a force for a creative decision. By objectifying a procedure, theory turns it into a potential object of contestation both by organizing and constructing a platform on which criticism becomes possible and pertinent. The split between theory and a computationally oriented contemporary practice can thus be seen as the misfit between these two theoretical cultures: one based on ideological premises and the other oriented towards quantitative analyses.

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<sup>9</sup> Ockman, J. [2001]. “The Pragmatism/Architecture: The idea of the Workshop Project,” *The Pragmatist Imagination*. Princeton Architectural Press, 16-23.

<sup>10</sup> Hays, M. [2001]. “Reflections on the State of Theory,” *A+U*, [396], 8-9.

<sup>11</sup> McLeod, M. [2001]. “Theory and Practice,” *A+U*, [397], 15-8.

<sup>12</sup> Eagleton, T. [1990]. *The Significance of Theory*. Blackwell, 96.

## 2.2 Theory and architecture. Literature review

The number of theory anthologies recently published, has contributed to a wider academic and public attention given to architectural theory. However, it is worth pointing out that these same publications, which mainly focus on the development of architectural theory in the second half of the 20th century, virtually exclude texts regarding the relation between architecture and theoretical 'normative systems.' The most recent, Michael Hays's *Architecture theory since 1968* [1998], is driven by a socio-political ideological point of view, and does not highlight computational contexts. Neil Leach's *Rethinking architecture: a reader in cultural theory* [1997], draws much from a literary and "critical theory" agenda and again emphasis is given to sociological and structuralist aspects. Kate Nesbitt's *Theorizing a new agenda for architecture: an anthology of architectural theory, 1965-1995* [1996] is an anthology with emphasis on phenomenological and structuralist approaches to architecture theory. Christopher Alexander's "The City is not a Tree" is an exception in Nesbitt's book. Again, Alexander is the only author cited in Hanno Kruff's *A History of Architectural Theory. From Vitruvius to the Present* [1994], where "Notes on the Synthesis of Form" and "The Timeless Way of Building" appear somehow isolated and with no particular historical contextualization.

The anthology by Joan Ockman, *Architecture culture 1943-1968: A Documentary anthology* [1993], presents texts from Alexander's, "A City is not a tree," and Colin Rowe's "Transparency," but with no particular reference to the cultural environment of the Cambridge school, to which both Alexander and Rowe were intellectually affiliated. Max Bill and Tomas Maldonado's ideas are highlighted respectively in two essays, "Education and Design" and "New Developments in Industry and the Training of the Designer." David Capon's *Architectural Theory* [1999], represents a non-anthological collection that tries to set out the principles and doctrines that have governed twentieth-century architectural theory in the Western world, presenting a narrative where a hierarchy of concepts tries to unveil their philosophical and theoretical aspects. In this two-volume collection there are a few references to Christopher Alexander's "The City is not a tree" and "Notes on the Synthesis of Form", to Lionel March's "The Architecture of Form", Alan Colquhoun's "Typology and Design Method", Colin Rowe's "The Mathematics of the Ideal Villa and other essays," and Bill Hillier's "The Social Logic of Space". Noam Chomsky's "Syntactic Structures" is also featured.

The fact that mathematical or computational-related essays are mostly missing from these reference works, shows that despite the existence of a multiplicity of influences in the formulation of theoretical concepts during the twentieth century, there is still a predominant reading of the history of the proper content of theory. As Michael Hays had pointed out, "the coupling of Marxist critical theory and post-structuralism with the readings of architectural modernism has been what has dominated theory."

### 2.3 Science and architecture. Literature review

When historians look at the relationship between science and architecture they tend to present their perspectives in three major domains; first, an interpretation that goes back very often to the Renaissance as the origin of their historical explanation, a period when architecture and science had a strong cosmological affinity; secondly, a focus on the metaphorical character of the machine, corresponding to the heroic period of modernism; thirdly, the scientific spirit that characterized part of the architecture enterprise that emerged during the 60s. If the initial point is well illustrated by Alberto Pérez Gómez's, *Architecture and the Crisis of Modern Science*<sup>13</sup>, the second is fully exemplified in Reyner Banham's *Theory and Design in the First Machine Age*<sup>14</sup>, which critically maps out the compulsive aspiration of a new generation of architects to work with technology.<sup>15</sup> The third phase, the aspirations to "scientise design", is often analyzed through the research work conducted in the 60s, and which is often attributed to the "Design Methods Movement."<sup>16 17</sup>

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<sup>13</sup> Gómez, P. [1983]. *Architecture and the Crisis of Modern Science*. Cambridge, Mass: The MIT Press.

<sup>14</sup> Banham R. [1960]. *Theory and Design in the First Machine Age*. Cambridge, Mass: The MIT Press.

<sup>15</sup> See also, Siegfried Giedion's *Mechanization Takes Command*, a historical account that tries to see the world from a technological perspective, where mechanization is perceived as a procedure that should be produced and controlled by man.

<sup>16</sup> The Design Methods Group was formed in 1966 during the 'International Design and Planning Seminars' at the University of Waterloo in Canada. The movement toward new methods in architecture and industrial design first appeared in the thinking and teaching at Ulm, Germany in the 50s. In the USA the movement received a strong lead from the work of Christopher Alexander in 1964, although some research and teaching were already under way at Berkeley under Horst Rittel, who had come from Ulm in 1962. The Design Methods Group First International Conference, was held in Cambridge, Massachusetts, in June 1968.

For a comprehensive review on the work of the Design Methods Group, see, Broadbent, J. [1973]. *Design in Architecture. Architecture and the Human Sciences*. New York: John Wiley & Sons.

<sup>17</sup> Gottfried Semper's and Norberg Schults' historical projects, which attempted to construct a science of architecture, also constitutes a seminal reference work. Semper's enterprise was a response to the radical historicism of the nineteenth century, and should not be simplistically read as a form of reductive positivism. Instead, it pointed towards the beginning of an alternative proposal to construct a new path for architecture within a scientific domain.

To depict a more recent view of how historians examine the relationship between architecture and science, three essays from, *The Architecture of Science*<sup>18</sup>, by the historian Peter Galison, provide ample illustration. The first, by the French historian Antoine Picon, “Architecture, Science and Technology”, describes the relations between art and science from the XVII and XVIII centuries until the present. Here, he presents the idea that after an Aristotelic division between “natural beings”, who had inherited a natural condition, and “artifacts”, which were a second-generation conceptualizations, we enter a period in which the boundaries between the natural and the artificial start to be of difficult definition. According to Picon, this is due to the changing perception of phenomena, a contemporary interpretation in which ‘information’ starts to be the “omnipresent” feature, and where the computer starts to be seen as a natural “artifact”. This historical shift –“natural beings” versus “artifacts”- has some resemblances to Herbert Simon’s argument about the “artificial”, but even if Picon plays with this dichotomy and with certain analogies such as the computer as a machine of “programmed events”, he does not develop [any further] his notion in any kind of critical reading of contemporary architectural praxis.

This position contrasts with the main argument of the second essay, “Architecture as Science: Analogy or Disjunction?” by Alberto Perez Gómez. It begins by mentioning that the “contemporary architecture crisis” began precisely with the arrival of modern science. The collision of the new epistemological contexts of the XVII century with architecture determined the demise of the old cosmological order of architecture and theory. ‘Meaning’, is no longer seen through the relation between man-nature, but in the course of the construction of languages. Perez Gómez pointed out, “In a certain sense, Perrault was merely continuing the tradition of architecture as science. Yet he radically transformed the nature of architecture theory and practice.”<sup>19</sup> This transformation heralds the beginning of the end of traditional architecture, which according to Perez Gómez materialized with J. Durand’s theory in the XIX century. For the first time the architect’s concern with “mathemata” becomes formal, something that was never the case before. Gómez gives the example that not even the five Vitruvian categories were ever perceived as independent identities, as they had other values in themselves.

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<sup>18</sup> Galison, P and Thompson, E. [eds] [2000]. *The Architecture of Science*. Cambridge, Massachusetts. London: The MIT Press.

<sup>19</sup> Gómez, P. [1983]. *Architecture and the Crisis of Modern Science*. Cambridge. Mass: The MIT Press, 339.

For Picon, a few current practices are also characterized by the formalistic use of concepts such as the “Chaos theory”, “Fractals” or developments in modern biology, which for Gomez seem “dangerously irresponsible” if used within architecture theory. The argument closes in a clouded vertice, neither presenting a possible way to pursue reflection upon the raised issues, nor making an in-depth analysis of contemporary practice.

The third essay, Kenneth Frampton’s “The Mutual Limits of Architecture and Science,” addresses a more contemporary interpretation of the theme. It offers a critique of some of the Anglo-Saxon architectural experiments of the 60s, namely the work produced at LUBFS. However, it seems to us that Frampton’s analysis may be ill defined, as his perspective on LUBFS work seems to focus only on the “effort to reconstitute architecture as an applied science.” Interpreting the LUBFS premises only in the light of this modeling ‘lens’ is, in our opinion, ignoring the wider issue that both Leslie Martin and Lionel March were trying to address: understanding architecture as a whole, where rigorous research was the fundamental method through which architectural ideas would emerge and be put into practice. Moreover, the computational legacy initiated at LUBFS has evolved into a contemporary practice that should not be disregarded in any historical review. Further, in the same essay, Frampton shows some skepticism when analyzing the educational project initiated by Max Bill at the ‘Hochschule für Gestaltung’ [Hfg] in Ulm, Germany.<sup>20</sup>

Frampton’s text is significant in that it highlights part of the design curricula of one of the most important schools of design of the XX century, and one that was extremely important in broadening some of the scientific concepts that would later be investigated in other architectural research centers. During its existence [1955-1968], the hfg had three directors, the Swiss architect Max Bill<sup>21</sup>, the Argentinean painter Tomas Maldonado, and the German philosopher Max Bense. Although representing slightly different views, the courses designed by Tomas Maldonado and Max Bense laid particular emphasis on the use of mathematical logic as a basis to achieve a design method. Courses covered topics such as operations research, statistics, set theory, linear programming techniques, and discipline classes dealing

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<sup>20</sup> Hfg was a school where modern industrial design was shown as a cultural manifestation, and its educational project was built to bridge scientific disciplines where design was taught by means of precise rational methods.

<sup>21</sup> Max Bill had been one of Hannes Meyer’s students at the Bauhaus, bringing to the Ulm project part of the Bauhaus spirit, particularly the belief that the form of an object is mainly dependent on the interaction between its programmatic requirements and the rational methods of production.

with the history of science and the theory of machines. Interestingly, Maldonado acknowledges the importance of the British physicist, John Desmond Bernal, who held ideas regarding the use of combinatorics as a method to develop topological alternatives. Maldonado points out:

Lo scienziato inglese J. Bernal, nel 1937, fu uno dei primi a rendersi conto dell'importanza che la topologia avrebbe avuto in futuro per l'architettura e per la pianificazione urbana e regionale [si intende qui la topologia combinatorial o algebrica, non la topologia generale]. La previsione di Bernal si è avverata, almeno in parte. Se non per tutte le branche della topologia, almeno per una di esse: la Teoria dei complessi lineari o grafi, che possiede un notevole valore strumentale per la progettazione di edifici in cui si debbano risolvere problemi di circulations altamente compessi.<sup>22</sup>

Ulm represented the continued post-war project, to rethink the role of social science within a faith in the enlightened supremacy of reason. In this respect, in his essay "Apropos Ulm" Frampton says:

There is little doubt but that the Hochschule für Gestaltung' Ulm, has been the most significant school of design to come into existence since the end of WW II, not so much for what it achieved in terms of actual production, nor for the large number of designers it effectively educated, but finally for the extraordinarily high level of critical consciousness that it managed to sustain in its daily work [...]. The questions that the Hochschule began to ask a decade ago are now being asked, consciously or unconsciously, by every design and architecture school throughout the country, and the crisis of identity that befell the Hochschule has now become a universal malaise.<sup>23</sup>

The analytical approach with which the Ulm school became identified gave way in the mid 60s to heuristic procedures related to the increasingly seductive power of the computer. Picon, Gomez and Frampton, although presenting rigorous descriptions and interpretations of the relationship between science and architecture, still do not suggest many guidelines concerning the interweaving of theory [history] of science with architecture today.

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<sup>22</sup> Maldonado, T. [1964]. "Scienza e Progettazione," *Avanguardia e razionalità. Articoli, saggi, pamphlets 1946-1974*. Torino: Giulio Einaudi, 182. [Maldonado is referring to Bernal's, *The Freedom of Necessity*. Routledge & Kegan Paul, London. 1949, 193].

<sup>23</sup> Frampton, K. [1974]. "Apropos Ulm," *Oppositions* 3, 19.

## 2.4 "Critical theory." The transatlantic journey

In the late 60s, Peter Eisenman, who had been Leslie Martin student at the Cambridge school of architecture, made efforts to bring to the American debate some of the cultural ideas that were flourishing in Europe. This led to the foundation of IAUS in New York, which constituted a remarkable enterprise particularly within the architectural field as the US was still living the culture of the 'International Style', and many of the social, ideological, and political issues which were being debated in some European milieus were not a current presence in the US. As the historian Joan Ockman pointed out, "the theoretical discourse in American architecture had always been meager, lagging well behind other aesthetic and intellectual disciplines."<sup>24</sup> This cultural bridge between the two sides of the Atlantic culminated a few years later with the publication of the first issue of *Oppositions* in 1974, the official journal of IAUS, where much of the theoretical and ideological work that was being conducted in Europe - mainly at Istituto Universitario di Architettura di Venezia [IAUV], Italy, which was closely connected with the ideas of the Frankfurt School - began to be published.<sup>25</sup>

Within *Oppositions* the texts of Manfredo Tafuri represented a continued debate about the importance of "critical theory" as an instrument that could be used within architecture as a medium to unveil hidden ideological layers of cultural production inside western capitalist society. Tafuri was one of the first European historians to read modern architecture in the light of a leftist ideological and philosophical influence and his writings served as a theoretical mediator to propose a method of historical criticism, where architectural history was woven into social, economic and political contexts.<sup>26</sup>

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<sup>24</sup> Ockman, J. [1995]. "Venice and New York," *Casabella*, [619-620], 59.

<sup>25</sup> For a detailed study of the *OPPOSITIONS* program and its relation to IAUS, see, Ockman, J. [1988]. "Resurrecting the Avant-Garde: The History and Program of *Oppositions*," *Architecture reproduction*. [Beatriz Colomina, Eds]. Princeton Architectural Press, 181-99.

<sup>26</sup> Tafuri arrived in Venice when his *Teorie e Storia dell'architettura* had just been published [1970]. In Venice, Tafuri soon met Massimo Cacciari who, with Alberto Rosa and Toni Negri, were the founders of *Contropiano*, a journal of Marxist influence. Tafuri started to teach at the Istituto Universitario di Architettura di Venezia in that same year, initiating an intellectual collaboration with the movement around *Contropiano*, and becoming one of the most prominent members of the group. This collaboration was probably ignited by Francesco Dal Co, who, being one of Tafuri's first students was also with Cacciari an effective member of the journal *Angelus Novus*, a periodical that highlighted the writings of Walter Benjamin and those of the Frankfurt School, of which *Contropiano* and *Angelus Novus* were a catalyst for the discussion of political and aesthetic ideas. Two years before founding the Dipartimento di Analise Critica e Storica dell'Architettura dell' Istituto Universitario di Architettura di Venezia [IAUV]. Tafuri was invited by Diana Agrest, in April 1974, to take part in a lecture series entitled 'Practice, Theory and Politics in Architecture' at Princeton University. Diana Agrest was at that time at the Princeton faculty, as well as a fellow of the IAUS, and introduced Tafuri to the IAUS circle. According to Ockman, Tafuri's first presence in the USA was in 1970, after written correspondence with Rudolf Wittkower. See, Ockman, J. "Venice and New York," *Casabella* [619-620], 67-71.

The ideological and philosophical foundation of Tafuri's project in this way passed for the first time into an American architectural audience and its influence rested on two main sources: on Hegel's philosophy as a transitional figure between Kant's critical ideas and Marx's critical social theory; and on the sociological work of the Frankfurt Institute for Social Research. The Institute's critique of scientific knowledge and rationality was also an ideological rejection of capitalism, a system that according to George Luckas was depriving society of its freedom and true intellectual fulfilment. The Institute's first director, Max Horkheimer, influenced by Marx's own view that the course of history was not determined by philosophical ideas, but rather by the relation between material production and labour, between organization and distribution of wealth, published in 1937 an seminal essay entitled, "Traditional and Critical Theory."<sup>27</sup> Since then, "critical theory" has started to designate a school of thought which has been mainly identified as the 'Frankfurt School'.

All Marxist enterprise was then emphasising the historical conditions in which the object [art] was produced, explaining the object in its form and meaning as the product of a particular history of labour and power interdependency. This is what Marx called a "revolutionary understanding of history itself", meaning that the social and creative production of ideas are a consequence of the "relations of production", which correspond to definite stages of social hierarchies. Marx says, "The sum total of these relations of production constitutes the economic structure of society, the real foundation, to which correspond definite forms of social consciousness."<sup>28</sup> This means that from an architectural point of view, Marxist critique was also taken as a sociological method that unveiled the relations of power and production of the architectural object.

It is within this idea that social forces become the factors that determine man's social consciousness that the philosophers George Simmel, George Luckas, Louis Althusser and Walter Benjamin later developed their sociological critique. They were also a defining influence on Tafuri's construction of a critical reading of architectural modernism, which found in Kenneth Frampton one of the most active advocates of "critical theory" in the US, through IAUS and its journal *Oppositions*.

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<sup>27</sup> Horkheimer, M. [1937]. "Traditional and Critical Theory." It described the necessity of integrating philosophy and social science, and of developing a relationship of integrity between critical theory and political practice. Along with Erich Fromm and Herbert Marcuse, Horkheimer was co-founder of the Institute for Social Research in Frankfurt where he becomes director in 1931. Due to the war Horkheimer immigrates in 1934 to the USA and sets up again the Institute for Social Research at the Columbia University in New York.

But this discourse did not evolve isolated from a wider context, one in which the ideas regarding Structuralism and its theoretical application to the field of architecture were also under discussion. This is what we highlight in the next chapter.

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<sup>28</sup> Marx, K. [1849]. "Wage-Labour and Capital". New York: International Publishers, 19-21.

## CHAPTER 3 Quantitative thought . The 60s

### 3.1 The question of origin[s]

Although we do not believe that any system can be completely explained in terms either of its origins or of its ultimate conclusions, we attempt in this chapter to chart a range of origins concerning the relationship between architecture and computation, as this may lead to some new historical insights. In so doing we try to unveil cultural and computational trends that led to the emergence of computation within the discipline of architecture.

The hypothesis we suggest is that during the 60s and early 70s, there was a split in the ‘theoretical transfer’ from the field of structuralism studies into architecture. If one part of the architecture milieu accepted a view of structuralism, which had its early premises in the writings of the Swiss linguist Ferdinand de Saussure, another, not so much concerned with the inner relationships between the Saussurien notions of “langue” and “parole”, received the development of mathematical models as new operative and theoretical tools. While the former context gave rise to a transatlantic relationship between Paris, Venice, and New York, finding at the IAUS the venue for the diffusion of its structuralist views the latter found in Cambridge, UK an ideal scientific setting for the fruition of a rigorous mode of mathematical thinking which, promoted by Lionel March at LUBFS, soon started to be embedded in architectural research.

The Enlightenment legacy, interest in rigorous modes of “structural” thinking: the importance given to the study of language, to its structure, its sign systems [semiotics], and to artificial languages, all permeated a renewed awareness of origins for architecture theory.

### 3.2 The quantitative revolution. Structuralism and Modeling

Structuralism has its roots in the work carried out by Saussure on the nature of language and sign-system structures.<sup>29</sup> As a major discipline, it allowed the multiple transfer of “structural” knowledge into different fields, and gained a foothold due to the ideological atmosphere prevailing in France through the works of the anthropologist Claude Levi Strauss, the philosophers Michel Foucault, Roland Barthes, and Louis Althusser.<sup>30</sup> Although the overlap of their ideas was never seen as a unified movement, it constituted an influential field of thought that also found a welcome in Britain and in the USA. The “structural revolution” brought to

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<sup>29</sup> Saussure, F. [1959]. *Course in General Linguistics*. New York: Philosophical Library.

<sup>30</sup> Intellectuals in Paris, Venice, Frankfurt, Prague, and Cambridge developed different views of structuralism.

disciplines such as linguistics, anthropology, geography and architecture a different way to interpret phenomena. Building blocks of matter, whether social, economic, literary, or psychological, are found in our environment, and the inner relations between these elements produce “universal patterns,” that allow us to organize the perception of phenomena in a new “structural” way. According to Lévi-Strauss these same patterns are what constitute cultural systems, which are analyzed in terms of the structural relations among their elements. In the words of Levi-Strauss, “Structural studies are, in the social sciences, the indirect outcome of modern developments in mathematics [...] it has become possible, therefore, to develop a rigorous approach to problems.”<sup>31</sup> The structuralist method not only encompassed the ideas put forward by the French structuralists, but also fostered the field of semiology<sup>32</sup>, and in the course of new studies on the nature of language [based on the theories of the linguist Noam Chomsky<sup>33</sup>] formed a new intellectual background, which would soon started to be theorized by architects. This transformation, which involved the mathematization of many disciplinary fields - through the appliance of set theory - tried to reveal the structural patterns that lay behind the surface of perceived phenomena. Patterns, which are organized according to rules and considered as data for the construction and testing of theoretical models. In architecture these patters were interpreted in two major ways. First, as structural units [architectural sings], which were seen as sign-systems [semiotics] and secondly as syntactic building blocks [architectural vocabulary], perceived as ‘data’, which could be encoded in models, and subsequently developed in a computer program.

The major implication for design in this new scenario was that it started to be categorized as a step-by-step procedure within certain hierarchical structures. The work conducted by the architect Christopher Alexander represented one of the earliest models of design where an underlying structural correspondence between the pattern of the problem and the process of design was established [Fig. 26]. Following Alexander’s model, the designer was to organize first a complete list of requirements, form sets, and then cross-relate all these elements. A structural method.<sup>34</sup>

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<sup>31</sup> In, “Models of environment,” *Architectural Design*, [1971, May], 275.

<sup>32</sup> Initially through the work of the American mathematician and philosopher Charles Pierce.

<sup>33</sup> Chomsky, N. [1957]. *Syntactic Structures*. 's-Gravenhage, Mouton.

<sup>34</sup> See: Alexander, C. [1964]. *Notes on the Synthesis of Form*. Cambridge: Harvard University Press.

The first approach was mainly theorized by the Argentinean architect and theorist Mario Gandelsonas<sup>35</sup>, whose early writings published in the journal *Oppositions* tried simultaneously to theorize semiotics and formal architectural experiments. His "Semiotics and architecture: Ideological Consumption or Theoretical Work"<sup>36</sup> epitomized the differences between the notion of *communication* and the notion of *signification* and in "From Structure to Subject: the Formation of an Architectural Language"<sup>37</sup> Gandelsonas critically reviewed Peter Eisenman's 'House Series' syntactic operations, where the influence of Chomsky's theories appeared as an early theoretical structural method applied to architecture<sup>38</sup>. For Gandelsonas, these experiments inherited the formal system of Palladio's Villas, where architecture left its pure cosmological and classical order, to embrace mannerist combinatorics.

It was in Cambridge however that the latter influences were largely discussed and put into practice. A modest book entitled *Models and Analogies in Science*<sup>39</sup>, written by Mary Hesse, a Cambridge mathematician and philosopher of science, widened the discussion about the idea of modeling and quantitative analysis within the Cambridge architecture scene. This work emphasized that the creation of a model is just another representation of reality, one in which representation [modelling] is the expression of certain relevant characteristics of the observed phenomena. Under the influence of Mary Hesse's book, Lionel March developed the concept of modeling applied to architecture and that would be used as a framework of research and teaching.<sup>40</sup> The architect and planner Marcial Echenique who was by then conducting research at LUBFS, defined this process as follows:

Reality may be known through the process of observation and abstraction, but these processes are subjective in as much as the observer, in making his observations, has certain intentions and, in his appraisal of reality, uses his own senses. The means chosen to represent selected characteristics of reality may be physical or conceptual. Any such representation of reality is a model. The main purpose of a model is to provide a simplified and intelligible picture of reality in order to understand

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<sup>35</sup> Gandelsonas had studied semiology at The L' Ecole Pratique des Hautes Etudes, Paris.

<sup>36</sup> Agrest, D and Gandelsonas, M. [1973, September]. "Semiotics and Architecture: Ideological Consumption or Theoretical Work," *Oppositions* 1, 93-100.

<sup>37</sup> Gandelsonas, M. [1979]. "From Structure to Subject: the Formation of an Architectural Language," *Oppositions*, 17, 6-29.

<sup>38</sup> Here Eisenman through permutations on a fix vocabulary tries the reinvention of an architectural code/language where individual units did not represent any 'form', but rather quantitative measures of an architectural intention.

<sup>39</sup> Hesse, M. [1963]. *Models and Analogies in Science*. London, New York: Sheed and Ward.

<sup>40</sup> March, L. [1975]. "Models Modes and Mores," *LUBFS Conference Proceedings N° 3*. [Richard Baxter, Marcial Echenique and Janet Owers, Eds]. The Construction Press Ltd, 301-21.

it better. It should be possible to manipulate the model in order to propose improvements in the reality.<sup>41</sup>

Modelling was also pictured in the outstanding work of Peter Chorley;<sup>42</sup> his *Models in Geography* showed how quantitative approaches to landform evolution and spatial analytical theories were important to the field of Geography and both David Clark's book *Models of Archaeology*,<sup>43</sup> and Herbert Simon's *The Sciences of the Artificial*, brought a new intellectual background that would influence architecture studies, particularly in Cambridge where philosophy of science had always represented a high intellectual tradition.<sup>44</sup> Within architecture, the idea of modelling started thus to gain a foothold for a renewed practice, an operative concept that embodied much of the theoretical concerns that Leslie Martin had already expressed in 1958, at the Oxford Conference. Martin said: "Furthermore, the universities will require something more than a study of techniques and parcels of this or that form of knowledge,"<sup>45</sup> alluding thus to the lack of rigorous thinking that the architectural profession was facing. This general discontent regarding the absence of theoretical foundations in architecture and physical planning, was also manifested by Lionel March:

It is no longer enough to rely on intuitive skill acquired through personal experience: skill must become socialized, scientific, orderly accumulative, and criticisable on a sound objective basis [...] the environmental problems we face are too serious to be left to individual hunches.<sup>46</sup>

This happened during a period when architectural theory was being confined to multiple constructions of reality. Robert Venturi's *Complexity and Contradiction in Architecture*, Aldo Rossi's *Architecture and the City*, Leslie Martin's "Land Use and Built Form" essay, and Alan Colquhoun's essay "Typology and Design Method"<sup>47</sup> were all seminal texts of 1966.

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<sup>41</sup> Echenique, M. [1968]. "Models : a Discussion," *Working Paper 6*. Cambridge University School of Architecture.

<sup>42</sup> Chorley, R. [1967]. *Models in Geography*. [Richard Chorley and Peter Haggett, Eds]. London: Methuen. 'Models in Geography', was a series of annual summer conferences held at Madingley Hall near Cambridge, where the lectures given formed the basis of this series of volumes.

<sup>43</sup> Clarke, D. [1978]. *Analytical Archaeology*. London: Methuen, 1968.

<sup>44</sup> For a detailed account of the 'structural' atmosphere in the 60s see: March, L. [1972, March]. "Modern movement to Vitruvius: themes of education and research," *RIBA Journal* 3, 102.

<sup>45</sup> Martin, L. [1958]. *Conference on Architectural Education*. *RIBA Journal* [65], 8, 279.

<sup>46</sup> March, L., Echenique, M., Dickens, Peter et al. [1971, May]. "Models of Environment. Polemic for a Structural Revolution," *Architectural Design*. Volume XLI, 275.

### 3.3 Tafuri and the critique of artificial languages

The raise of structuralist studies at the end of the 60s and the application of its concepts in architecture led to particular sort of architectural critique and Manfredo Tafuri was one of the historians who more radically presented his reading of that theoretical and cultural phenomena. Architectural intentions are one of the principal aspects to be taken into consideration when we attempt to design and implement computational models. The matter of intentions - prior to 'form' - and the matter of 'typology' were at the very beginning of the discussion regarding the relationship between architectural intentions with rules definition. Colin Rowe's seminal essay "The Mathematics of the Ideal Villa"<sup>48</sup> which created the basis for a mathematical and formal system capable of encompassing different cultural and historical formal references and Manfredo Tafuri's "Architecture and its Double: Semiology and Formalism,"<sup>49</sup> symbolized two poles of the debate about syntactic readings of architectural 'form'. Rowe's view was very much influenced by his mentor the historian Rudolf Wittkower, whose *Architectural Principles in the Age of Humanism*<sup>50</sup> influenced a whole generation of post-war architectural students, particularly Cambridge students such as Eisenman and Rowe who later would attempt to extend humanist ideals beyond their specific historical contexts.<sup>51</sup> However it was Tafuri who first and foremost tried to analyze and interpret the implications of the use of "formal systems" as theoretical matters within architecture. In his seminal essay "Architecture and its Double" Tafuri says:

We might begin by observing that the proliferation of semiological studies relative to various areas of intellectual work [literature, films, architecture, the argument varies little] coincides with new impulses given to the study of highly formalized languages. These researches are made necessary by the new possibilities that the extensive use of cybernetics has opened up. Corresponding to the new branches of mathematics created for the study of the dynamic models - the theory of automata - are new techniques which make it possible to define and analyze artificial-languages

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<sup>47</sup> "Typology and Design Method," was first published in *Arena*, vol. 83, June 1967.

<sup>48</sup> Rowe, C. [1947, March]. "The Mathematics of the Ideal Villa," *The Architectural Review*, 101-09.

<sup>49</sup> Tafuri, M. [1976]. *Architecture and Utopia: Design and Capitalist Development*. Cambridge, Mass: MIT Press.

<sup>50</sup> Wittkower, R. [1949]. "Architectural Principles in the Age of Humanism." London, Warburg Institute, University of London.

<sup>51</sup> Rowe after graduating pursued his studies at the Warburg Institute in London under Rudolf Wittkower's guidance with a thesis on the drawings of Inigo Jones. Later between 1958 and 1962, Rowe was appointed Lecturer at Cambridge University and with Peter Eisenman visited Italy to study Terragni. Later Eisenman's PhD thesis realized under the supervision of Leslie Martin, presented part of the work that he did about Terragni. See: Eisenman, P. [1970]. "From object to relationship: the casa del Fascio by Terragni," *Casabella* ; and Eisenman, P [1971]. "Notes on Conceptual Architecture. Towards a Definition." *Casabella*, [350-360], 50-8.

systems such as the “generalized programming languages,” the “conversational languages” used for dialogues between computers, as well as between managers and computers, and the “languages of simulation.”<sup>52</sup>

This illustrates how Tafuri was aware of the developments in the field of hard sciences, however his interpretation of the use of “highly formalized languages” was perceived from a Marxist point of view. For Tafuri the use and creation of artificial languages was only a more sophisticated order of bourgeois control, the organization of systems that: “Connected as they are to capital’s extension of the use of science and automation, these languages are systems of communication that come into being from a plan of development.”<sup>53</sup> For Tafuri these new computational tools were at the forefront of a global project to maximize production, thus perpetuating the economic difference between those who produce goods from those who own goods. He adds:

In this respect the creation of such “artificial languages” is connected to the development of techniques of scientific prevision of the future and to the use of the “theory of games” in the realm of economic programming. That is to say, we are witnessing the first –still utopian- attempt at capital’s complete domination over the universe of development.<sup>54</sup>

This text, which appeared for the first time in 1969 in the Italian magazine *Contropiano*,<sup>55</sup> is remarkable as it reviews the historical condition of the avant-garde as “sign” users, avant-garde producing and operating simple building blocks for the construction of their project. In so doing, avant-garde artists, according to Tafuri, avoided any possible revolutionary undertake in the social tissue where they operated. Reviewing first the positions of the philosophers Wittgenstein, Carnap, and Frege - whose contributions were seminal to establishing the fields relatives to grammar, logic and semiology - and later the work of El Lissitzky’s *Proun* and of Kasimir Malevich, Tafuri asserts that, “the only utopia that the art of the avant-garde was able to proffer was the *technological utopia*,” this because of the

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<sup>52</sup> Tafuri, M. [1976]. *Architecture and Utopia: Design and Capitalist Development*. Cambridge, Mass: MIT Press, 151.

<sup>53</sup> *Ibid.*,151.

<sup>54</sup> *Ibid.*,152.

<sup>55</sup> *Contropiano* 1 [January-April 1969], “Per una critica dell’ideologia architettonica”. Tafuri expanded the essay as *Progetto Utopia* [Bari: Laterza & Figli, 1973], which appeared in English as *Architecture and Utopia: Design and Capitalist Development*. [Cambridge, Mass: MIT Press, 1976].

discovery of the possibility of manipulating randomly the relationships between linguistic “materials”. Tafuri describes this endeavor:

Destroy all the symbolic attributes accumulated by the linguistic signs, purify the signs to the point of annihilation, articulate their relationships on the basis of a complete freedom of relations: these are all operations depending directly on the rules, the law on which avant-garde theory was structured.<sup>56</sup>

These same individual units would later in the 60s foster a second artistic enterprise, particularly this time through works in music – serialism - and in sculpture, to which architecture was not alien. The American musicians La Monte Young and Steve Reich's<sup>57</sup> pioneered the field of serial music, with and Sol Witt's cube variations were artistic manifestations of this new spirit, which also constituted an influence on Peter Eisenman's work. Eisenman's experiments were thus an all-theoretical apparatus where concepts relative to 'generative grammars' and 'serialism' were applied, but nonetheless Tafuri is critical to this kind of form process:

An architecture that has accepted the reduction of its own elements to pure signs, and the construction of its own structure as an ensemble of tautological relationships that refer to themselves in a maximum of “negative entropy” – according to the language of information theory” – cannot turn to reconstructing “other” meanings through the use of analytic techniques which have their origins in the application of neo-positivist theories.<sup>58</sup>

Tafuri criticized these approaches because they would never “explain” the genuine sense of a work as these processes are, “based on yes-no, correct-incorrect, precisely analogous to the mathematical logic that guides the functioning of an electronic brain.” Nonetheless in his critique, Tafuri failed at least to suggest a better way through which architecture could itself be liberated from the proper forces of 'capitalism'. However his attitude should set an example for modern historians that must focus on the creative aspects of architectural

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<sup>56</sup> Ibid., 154.

<sup>57</sup> Steve Reich graduated with honours in philosophy from Cornell University in 1957 with a thesis about Wittgenstein.

<sup>58</sup> Ibid.,161.

processes [generated by computational means] as a new way to establish a legitimate path of criticism and of historical awareness.

### 3.4 Models, simulation and simulacra

The “structural revolution“ constituted part of a larger philosophical debate where the quest for scientific truth emerged as a dominant concern. Despite other tendencies, throughout the XX century; logic and language ruled supreme; and the creation of computer languages inaugurated a new epistemological ‘reservoir’ ready to be embodied by different disciplinary fields. Disciplines, which had already been given a mathematical form, rapidly started to incorporate these new mathematical and computational features, however this was not the case with architecture, neither with other less mathematized courses, such as psychology, biology, economics or linguistics. Soon the need to profit from the new research strategies made possible by the use of the computer required that old assumptions and previous beliefs would be modified or complemented. As the physicist and philosopher of science Thomas Kuhn pointed out, “The decision to reject one paradigm is always simultaneously the decision to accept another, and the judgment leading to that decision involves the comparison of both paradigms with nature and with each other.”<sup>59</sup> The potential to create computational models as a medium to represent and/or create formal solutions to architectural problems, represented part of this new paradigm within architecture. In this regard Christopher Alexander was pioneer in trying to establish a foundation that would allow the contextualization and inquiring of this endeavor. We call to mind Alexander’s words:

Anybody who asks, “how can we apply the computer to architecture? is dangerous, naïve, and foolish. He is foolish, because only a foolish person wants to use a tool before he has a reason for needing it. He is naïve, because as the thousand clerks have shown us, there is really very little that a computer can do, if we do not first enlarge our conceptual understanding of form and function. And he is dangerous, because his preoccupation may actually prevent us from reaching that conceptual understanding, and from seeing problems as they really are.”<sup>60</sup>

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<sup>59</sup> Kuhn, T. [1996]. *The Structure of Scientific Revolutions*. Chicago: The University of Chicago Press, 77.

<sup>60</sup> Alexander, C. [1964, December]. “A Much Asked Question about Computers and Design,” Speech at ‘Architecture and the Computer’ at the Boston Architectural Center [7 pages document]. Serge Chermayeff Archive, Avery Library, Columbia University. NY, NY.

The importance of enlarging the conceptual view of form and function founds in Leslie Martin a similar interpretation. Martin's thought about the importance of "intentions and processes":

I do not propose to speak about forms and images. Form is the end product of a process. I prefer to discuss what seems to me far more important to the architect: some of the intentions and the processes that cause forms to exist and give them their significance and meaning.<sup>61</sup>

These two readings, Alexander's and Martin's, can be interpreted in the light of the fact that one of the reasons to use and explore computers is that computation can be understood as an extended tool of thought. It allows thinking with a different and precise knowledge. It pushes the known boundaries of the discipline further, and it is our responsibility to define and understand those same boundaries. In so doing, we will engage a meaningful interactive process between rules, form definition, form evaluation, and 'form' generation. The architect conceives the computational system as an open source, where theory is embedded in the construction of the problem and creativity is a shared consequence of that process. In the Appendix we highlight some of these methods through the analysis of different case studies.

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<sup>61</sup> Martin, L. [1967, May]. "Architect's Approach to Architecture," *RIBA Journal*, 20.

## CHAPTER 4 Leslie Martin and the British Avant-garde

#### 4.1 **British Avant-garde**

The idea of a “third culture”<sup>62</sup> was already a concept at the heart of an intellectual and scientific milieu, which characterized London and Cambridge during the thirties, in regarding the relation of art and science as a social and cultural priority. This concern became fashionable when the search for an intense “structural unity” in artistic thought led to many of the innovative artistic paths undertaken in the UK: the rise of British Avant-garde between Hampstead, London and St.Ives, Cornwall, the advent of the 20<sup>th</sup> Century Group, the establishment of the Design Industrial Association [DIA], the foundation of the Modern Architectural Research Group [MARS] along with many discussion forums held in cosmopolitan London and at the scientific and ideological Cambridge, constituted some of the principal premises that nurtured a favorable environment for the emergence of modernism. During this period, Leslie Martin and Desmond Bernal were influential figures on the manner in which architecture would be related to science and to research, being ‘Constructive art’ the initial catalyst by which new ideas began to find expression.

#### 4.2 **The USSR goes to London.**

##### **Serge Chermayeff, Berthold Lubetkin, Naum Gabo: the pioneers**

The Russian revolution of 1917 did not fulfil many of the artistic and ideological expectations of its revolutionaries, and an early sense of frustration and isolation soon emerged. The natural escape route was to Germany, and so most of the prominent Russian artists started to move to Berlin [a center where interest in Constructivist ideas was burgeoning]. In October 1922, the ‘Van Diemen Galerie’ in Berlin, opened an Exhibition of Russian Art: ‘First Russian Exhibition’, an event that played a fundamental role in bringing a knowledge of Russian abstract art to a wider public and where the works of Naum Gabo, Kasemir Malevich, Aleksander Rodchenko, and Moholy-Nagy were displayed.<sup>63</sup> This exhibition represented the reopening of artistic frontiers with the West, as both the Russian civil war and WWI had banned any kind of cultural contacts between the two regions. This exhibit constituted the beginning of the spread of constructive art, which later, in Britain, would find its major expression in the publication of *Circle*, to which many of the Russian artists would contribute.

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<sup>62</sup> Snow, C.P. [1959]. *The two cultures: and a second look*. Cambridge University Press.

<sup>63</sup> See Catalogue: *The 1<sup>st</sup> Russian Show. A Commemoration of the Van Diemen Exhibition Berlin 1922*. Annelly Juda Fine Art, London [1983].

The pioneers of this first diaspora were Serge Chermayeff, Berthold Lubetkin and Naum Gabo. Both Serge Chermayeff and Berthold Lubetkin came from wealthy Russian families. Lubetkin's family was politically liberal and financially comfortable. In the year of the Russian revolution, he was an art student who later attended the Vkhutemas School in Moscow, and in 1922 went to Berlin as Lissitsky's assistant, for the first exhibition of soviet art outside Russia. During his three-year stay in Berlin, Lubetkin also attended lectures on reinforced concrete construction at the Bauschule. After Berlin he moved to Poland where he stayed for two years and received a more formal training in architecture at the Warsaw Polytechnic, studying a range of disciplines and covering many aspects of material science and structural design.

Following Poland, Lubetkin moves to Paris where he lived between 1925 and 1931. During this staying besides a renewed acquaintance with Russian émigrés, Lubetkin had the opportunity to share the rich and liberal artistic atmosphere of the Parisian avant-garde, where he made friendship with the painters George Braque and Fernand Leger, Pablo Picasso and Jean Cocteau. He also pursued studies at the École Supérieur de Béton Armé at the Ecole des Beaux Arts under August Perret, who was at that time one of the leading engineers and constructors and also an influential figure in the development of the modern movement. In the year of Lubetkin's arrival to the French capital, the 'Paris Exposition des Arts Décoratifs' was held and Lubetkin found a job translating Konstantin Melnikov's drawings of the soviet Pavilion into drawings that could be read by French contractors. He became job architect and construction manager.

Like Le Corbusier's celebrated 'L'Esprit Nouveau' pavilion, which stood just opposite the USSR pavilion, Melnikov's building became a milestone in the development of modern architecture. During his stay of five years in Paris, Lubetkin enlarged his knowledge in architecture, particularly his interest in reinforced concrete, a practical skill that would allow Lubetkin to work with the engineer Ove Arup, constituting one of the most successful associations in the emergence of modern architecture in Britain. A propos of this professional relationship Arup said:

He [Lubetkin] came because we knew more about reinforced concrete than these French consulting engineers. 'Christiani and Nielsen'<sup>64</sup> were pioneers in new ways of construction; they

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<sup>64</sup> The Danish company that Arup worked for, first in Hamburg and then in London.

had practical knowledge about concrete. The French were still using it in imitation of steel, because a new material is always first used in imitation of something else.<sup>65</sup>

While in Paris, Lubetkin lived with Prascovia Schbersky [Fig.1], a science graduate from Newnam College, Cambridge who had been a flat mate of Margaret Gardiner and in 1930 when Lubetkin visited London with Schbersky, he was introduced to Margaret, who had earlier moved from Cambridge to London. It was due to Gardiner's friendship with Godfrey Samuel, a young London-based architect, the architect Wells Coates, the Cambridge economist Jack Pritchard, and with many of the Bauhaus figures that started to arrive in London, that Lubetkin was introduced to the London Avant-garde of the thirties. It was within this milieu Lubetkin produced the first emblematic modern building in the UK, the Gorilla house project in Regent's park, London [1932-33], Chermayeff was the first foreign architect to establish himself on the London scene.

Chermayeff was the son of a wealthy family, and was born in 1900 near Grozny. His original name was Sergei Ivanovitch Issakovitch and at the age of ten he was brought to London by his father to enter a preparatory school in Hampstead, London. At the outbreak of the October Revolution, his family, who were in the oil business, lost their money, and although he had been accepted to attend Trinity College, Cambridge, he was unable to enroll as a student. After a period in Europe and Argentina, despite a sojourn in Paris at the Ecole des Beaux Arts, and in Germany, probably at the Bauhaus, Chermayeff returns to London, in 1924. Although he did not receive a full training in architecture, it is at that time that his career in art and design began to take shape. Due to his cosmopolitan education and way of living, Chermayeff had close contacts with all the founding figures of international modern architecture, Walter Gropius, Le Corbusier, Mies van der Rohe and Frank Lloyd Wright and played a key role in the establishment of a new design culture in the UK.

Last, Naum Gabo, who would play a major role in the diffusion of constructive ideas in the UK, had just moved to Berlin from Moscow in 1922, where he would stay for 10 years before going to London in 1932. Gabo was born in Russia in 1890, with a scientific education, he was an artist who did not renounce the scientific concepts of a new era and his art ideals which formed the 'Constructivist Manifesto' [1920] soon were sown in UK with the publication with Leslie Martin of *Circle*.

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<sup>65</sup> Interview of Lance Knobel to Ove Arup. *Domus* [646].

### 4.3 Cambridge and the 'Finella' house

The birth of English modernism emerged within the interwar period, it was influenced by a leftist ideology- very much as a reaction to the right totalitarian regimes of German and Spain- and as mentioned before, benefited from the arrival of a foreigner intelligence to the territory. By the mid 20s, the political and academic environment of Cambridge led naturally to the emergence of different clubs where this context started to constitute the topic of debate. One of the most prominent of these private clubs where several figures of the Cambridge intellectual life would meet regularly was: the 'Society for Cultural Relations' [SCR] between the British Commonwealth and the Union of Soviet Socialist Republics, which promoted the renewal of the scientific, economic, and cultural relationships between these two blocs. At the inaugural meeting of the Society its chairman said:

Now, after worldwide war and the Russian revolution, a renewal of friendly relations and of the old interchange of ideas will be of great value to each country. The Union of Soviet Socialist Republics, into which Russia was transformed in 1923, has preserved intact, if anything intensified, its ideal of the spiritual independence of mankind. In science, in the achievement of literature and art [...] the USSR is showing constructive energy and is eager to share in the knowledge and progressive ideas of the British Commonwealth.<sup>66</sup>

The many distinguished members who supported the formation of the Society in May 1924 included the biologist J.B. Haldane, the zoologist Julian Huxley, the philosopher Bertrand Russell, the playwright Bernard Shaw and the writers H.G. Wells and Virginia Woolf. Other important clubs were: 'The Cambridge Scientists Anti-War Group' [CSAWG] was formed in 1932,<sup>67</sup> a date that coincides with the major anti-war campaign launched inside the university by the Communist party, being Desmond Bernal one of the leaders of the venture. Its initial prominence came with their participation in the nation-wide debate on the inadequacy of Britain's civil defenses due to the beginning of WWII, which later would lead to many of the Air Raid Precaution [ARP] plans. A matter that we will see in more detail in Chapter 5.

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<sup>66</sup> M. L. Davies [private report, May, 1924]. Document kindly provided by Prof. Catherine Cook.

<sup>67</sup> Eighty scientists, mainly from the Cavendish Laboratory, founded in 1870 [University of Cambridge, UK.], originally formed the group, driven by left-wing inspiration and concerned with pacifism and anti-fascism ideologies.

Another private club was the 'Tots and Quots',<sup>68</sup> a London-based dining club regularly convened by Solly Zuckerman, an Oxford biologist, and where J. D. Bernal, Aldous Huxley, Julian Huxley, and C.H Waddington also a biologist, would meet. During one of these meetings they produced a significant work on warfare entitled *Science in War* and which was published anonymously. The 'Heretics Club'<sup>69</sup> was one of the oldest, where many of those who would shape the future of British modernism would meet during the 30s; figures such as Jack Pritchard, Serge Chermayeff, Berthold Lubetkin, Wells Coates, Herbert Read, Barbara Hepworth, Naum Gabo, Julien Huxley, Virginia Woolf and Desmond Bernal, constituted an intellectual network that disseminated many of the artistic, political and scientific ideas that circulated between London and Cambridge. These allowed the emergence of a new social critical consciousness and the appearance of a new awareness and need for change.<sup>70</sup>

In the late 20s much of the new design ideology that emerged from this context, found a first application in the refurbishment of 'Finella'. Mansfield Forbes, a fellow of Clare College, Cambridge, acquired 'Finella' an old Victorian House on the outskirts of Cambridge and transformed into the modernist 'Finella' [Fig.3]. Acquired in 1927 it was in the "backs" of the Cambridge fields that 'Finella' stood and where, for more than a decade, it was the center for a cosmopolitan artistic life, where people from everywhere gathered to share the Forbes' hospitality. It was there that Chermayeff struck friendships with Henry Moore, Ben Nicholson, John Piper, Barbara Hepworth, the sculptor Eric Gill, Raymond McGrath, and due to this fruitful alliance, the '20<sup>th</sup> Century Group' with McGrath, Coates and Forbes was formed in 1930 and later it inspired the creation of the MARS Group [Fig.8]. The seed to discuss art, technology, and science, along with politics, was thus sown in Cambridge, and the arrival soon after in London of the leading Bauhaus figures increased the interest in the debate on notions of modern architecture and design. The 'Finella' environment was also seminal to the launching of an important architectural project; the refurbishment of the BBC headquarters in

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<sup>68</sup> The 'Tots and Quots' dining club, started in 1931 by Solly Zuckerman, then a 26-year old research anatomist at the London Zoo. Its title derivative from the Latin tag ' Quot homines, tot sententiae,' which can be freely translated as ' As many opinions as there are men.'

<sup>69</sup> The 'Heretics Club' founded in Cambridge by C.K.Ogden in 1909.

<sup>70</sup> For a detailed study of this period and particularly of the British Left Wing Scientists' history between 1919 and 1939, see: Werskey, G [1978]. *The Visible College*. London: Penguin Books.

London. McGrath, only 27 years old, was in charge together with Chermayeff 29, and Wells Coates, 34<sup>71</sup>.

'The three Musketeers,' as Chermayeff, Coates and McGrath were called, were thus responsible for the introduction of industrial design in England and Mansfield Forbes's spirit and the social events that 'Finella' fostered were the inspiration for what would happen in the early 30s in the cultural milieu of Cambridge and London.

#### 4.4 London and Hampstead . The emergence of *Circle*

The concepts of free enterprise and individual freedom no longer existed in George Orwell's,<sup>72</sup> *1984*, where only three superpowers remained to dominate a world of hate, isolation, and fear. Eurasia and Eastasia are two of these superpowers. Oceania, the other, is always at war with one of them. *1984*, written during Orwell's final days, warns of the dangers of life in a totalitarian state, a condition also featured by Aldous Huxley's *Brave New World* written in 1931, on the eve of the rise of the Nazi oppressive regime. For Huxley control was based on conditioning and drugs, rather than military might and terror, by technophobes and implemented by principles of mass production and consumption. Huxley's novel was in many ways a more accurate prophecy than Orwell's *1984* and one that anticipated much of the discussion that would follow about the misuse of technology and about the relationship between science and society. Somehow Bernal's *The World the Flesh and the Devil*<sup>73</sup> [1934] and *The Social Function of Science* [1939] epitomize a cycle of reflection that ranges from an utopian technological vision of society, to the implementation of a system that could effectively use science and technology in the benefit of all.

These themes come much to fruition among the 'Bloomsbury' group, an association of writers at the center of literary society in London. Aldous Huxley, Virginia Woolf, H. G Wells and

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<sup>71</sup> This commission took place due to the friendship between Forbes, and Lance Sieveking and Valentine Goldsmith of the BBC, who frequently visited Finella in the late 20s.

<sup>72</sup> George Orwell, British journalist, essayist, pamphleteer, and novelist distinguished for his writings about the social and political issues of his time. He was born on June 25, 1903, in Bengal, India and from 1922-1927 Orwell served with the Indian Imperial Police in Burma, where his experiences intensified his dislike of Imperialism. Between 1928-1934 he lived in Paris and London, where he worked a series of low-paying jobs while writing numerous articles and translations. In 1936 joined the anti-Fascists in Barcelona.

<sup>73</sup> The intriguing title *The World, the Flesh and the Devil* seems to be original. Interestingly to note however that in 1959 one film with the same title was released. *The World, the Flesh and the Devil* a sci-fi movie which story is related to the destruction of civilization. By director, MacDougall Randal and music composer Miklos Rozsa, is based on the novel *The Purple Cloud* by Matthews Phipps Shiel, [1901]. This novel also featured the theme of the "last man on earth." However no reference is made to Bernal's book title.

other intellectuals<sup>74</sup>, constituted it and they were also in close contact with the Hampstead group where the historian and art critic Herbert Read was one of the leading figures promoting the work of the British Avant-garde artists.

In one of his introductory notes Read wrote: "From 1930 onwards Henry Moore, Ben Nicholson, Barbara Hepworth and several other artists were living and working together in Hampstead, as closely and intimately as the artists of Florence and Siena had lived and worked in the Quattrocento."<sup>75</sup> Herbert Read was part of this same group, acting as a focal personage, and during this significant period of British modernism [Fig. 2a], he edited, in 1934, the catalogue *Unit* - followed the previous exhibition of works from Barbara Hepworth and Ben Nicholson [Fig. 9] - which represented much of the innovative artistic spirit that was being shared at the Mall Studios. *Unit 1, the modern movement in English architecture, painting and sculpture*, appeared as an initial manifesto promoting the art of the Hampstead group, including the works of Barbara Hepworth, Henry Moore, Paul Nash and Ben Nicholson; there were also two articles written by two up-and-coming architects, Wells Coates and Colin Lucas. At the outbreak of the war, the seed for the future of art in England had been sown and Barbara Hepworth in her autobiography mentions this period as an epoch of real maturity and at the same time acknowledges the importance of Herbert Read's friendship and criticism. About Herbert Read it was once said that he was to British Art what Alfred Barr<sup>76</sup> was to the American art. She says:

This was a period of real maturity. I met Ben Nicholson, and as painter and sculptor each was the other's best critic [...] work shaped up more and more strongly, and I prepared for my 1932 exhibition with Ben and Herbert Read, who wrote my foreword. This was the beginning of a period that the late Sir Herbert Read called "a gentle nest of artists" through the 1930s in Hampstead. Sir Herbert Read was gentle, and I think we all were because we were free and totally and individually dedicated.<sup>77</sup>

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<sup>74</sup> See: Shone, R. [1976]. *Bloomsbury portraits*. Oxford: Phaidon; New York: E. P. Dutton.

<sup>75</sup> Read, H. [1965]. Marlborough Fine Art Ltd. *Art in Britain, 1930-40, centred around Axis, Circle and Unit one*. [Catalogue of an exhibition], March-April 1965, Marlborough Fine Art, Ltd., and Marlborough New London Gallery.

<sup>76</sup> Alfred Barr [1901-1981]. Founding and director of the 'MOMA', New York.

<sup>77</sup> Hepworth, B. [1970]. *A Pictorial Autobiography*. New York: Praeger, 19.

The decade ended with the beginning of WW II, the threat of which brought to England artists who would be living within the Hampstead circle. The most influential were Naum Gabo, who came in 1935, Piet Mondrian, who came in 1938, Moholy Nagy and Walter Gropius, who came in 1934. Also the architects Serge Chermayeff, Berthold Lubetkin and Wells Coates, the writers, Aldous Huxley, H.G Wells, and Virginia Woolf were regular presences at Hampstead, a period when it was almost impossible to sell works of art, particularly abstract art. It was only with the continued support of a very few people that this new young generation of artists was allowed to pursue their work. Among those patrons were Leslie Martin and his wife Sadie Speight, Solly Zuckerman, Margaret Gardiner and her partner Desmond Bernal, Nicolette Gray and Jim Ede<sup>78</sup>, all regular presences within the Hampstead and St. Ives circles.

In the meantime the publication of the art magazines *Axis*, *Unit 1* and *Circle*, Herbert Read as the critic and spokesman for the British Avant-garde, and the entrepreneurship of Jack Pritchard, constituted a unique cultural context for the growth of a new artistic spirit in England, the true importance of which was only generally recognized much later. Science and art were then epitomized by the sculptures of Barbara Hepworth and Ben Nicholson, in the writings Bernal about the relationship between architecture and science, in the work of the Bauhaus members in London, in the uniqueness of the pre-stressed concrete structures of Ove Arup by Berthold Lubetkin's architectural projects and by Wells Coates's Lawn Road Flats. This new scent of artistic phenomena comprised an inheritance of scientific rigor and a new desire for discovery that found both in the scientific context of Cambridge and in the artistic spirit of Hampstead, the ideal setting for a merging of cultural and scientific beliefs.

#### 4.4 *Circle*

The 'Finella' environment somehow faded around 1932, when Mansfield Forbes moved away, but many of the artistic connections and intellectual discussions that had taken place would now continue in Hampstead, London. As Lionel March observed, the "extraordinary galaxy of genius"<sup>79</sup>, were the future participants of *Circle*, all living at The Mall Studios, in Parkhill Road, Belsize Park. Ben Nicholson, Barbara Hepworth and Henry Moore shared studios. Nearby lived Herbert Read, Adrian Stokes, Helen Gardner and Jim Ede. All

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<sup>78</sup> Last curator of Kettle's Yard Gallery, Cambridge.

<sup>79</sup> March, L. [1971, October 22]. "Circle." *Cambridge Review*, 93 [2204], 4.

constituted a community with common ideals about art, which remained settled between 1932 and 1939. This cultural atmosphere was very attractive to other European exiles that shared similar artistic beliefs. Walter Gropius, Marcel Breuer and Eric Mendelsohn had lived at the Lawn Road Flats since 1934, also in Hampstead. Laszlo Moholy-Nagy came in 1935 and Piet Mondrian arrived in 1939 to live in a studio in Parkhill Road, next to the Mall studios. Naum Gabo, who was undoubtedly encouraged by the presence of fellow émigrés he had met in Germany, moved to England in 1936<sup>80</sup>, where he stayed for more than a decade [Fig. 2a]. The three and a half years he spent in London, before leaving for Cornwall at the outbreak of the Second World War,<sup>81</sup> acted as a catalyst in the emergence of English Constructivism. During this period he became particularly close to Ben Nicholson, Barbara Hepworth, Leslie Martin, and Herbert Read, whose presence and criticism constituted a magnet that brought people and ideas together in the Hampstead circle.

Later, the 'Abstract & Concrete Exhibition' held during 1936 in Liverpool, Newcastle, Cambridge and finally at the Lefevre Gallery in London, constituted the first serious view of the international abstract movement in which the works of Mondrian, Kandinsky, and Gabo were represented side by side with the works of Ben, Barbara, Moore and Piper<sup>82</sup>. These artistic settings led, later on, to the appearance of *Circle, The International Survey of Constructive Art*<sup>83</sup>, which was probably the major collective contemporary record of those years. Without being a manifesto, *Circle* was one of the earliest and most important projects to promote the confluence of ideas and people that were arriving in Great Britain prior to WWII; one which allowed Leslie Martin to create a unifying vision of a new cultural environment. When, in 1982, Kettle's Yard Gallery, Cambridge, celebrated the 45th anniversary of the publication of *Circle*, Leslie Martin wrote:

Above all else, *Circle* was, I think, an attempt in a period of considerable confusion, to achieve a clarification and to demonstrate by illustration, examples of a particular attitude of mind that seemed to be valid and at work in art and architecture.<sup>84</sup>

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<sup>80</sup> Naum Gabo arrived in London on 25 March 1936, in time for the opening of the 'Abstract and Concrete' exhibition at the *Lefevre Gallery*. Gabo probably encountered everyone involved in this small community at the 'Abstract and Concrete' opening.

<sup>81</sup> To join Ben Nicholson and Barbara Hepworth in St. Ives, UK.

<sup>82</sup> Gabo recalled seeing Martin for the first time at the 'Abstract & Concrete Exhibition.'

<sup>83</sup> Martin, L., Gabo, N and B. Nicholson. [1937]. *Circle. The International Survey of Constructive Art*. London: Faber and Faber.

<sup>84</sup> Martin, L. [1982]. *Circle. Constructive art in Britain 1934-40*. Kettle's Yard Gallery [Jeremy Lewison, editor], 9.

There is no doubt that the work illustrated in *Circle* was the basis for subsequent developments. It aimed at highlighting the British contribution to the European abstract movement, and setting it within a wider context, a far more purist attitude towards abstraction and towards a certain contemporary "cultural unity" [Fig. 10]. This artistic endeavour received contributions from Aalto, Breuer, Chermayeff, Corbusier, Lubetkin, Gideon, Gropius, Gabo, Bernal, among many others architects, painters and sculptors.

It is worth to acknowledge the genesis of *Circle* as it shows how well the Martins were related to the British Avant-garde. Around 1932 Barbara Hepworth introduced Ben Nicholson to her close friend Margaret Gardiner, who would become close to Leslie Martin's wife, Sadie Speight. Martin and Sadie, in the mid-thirties were living in Hull, in the north-east, and had initially approached Ben and Barbara as art collectors. Soon they became part of Ben Nicholson's group, spending many hours discussing the future of art and architecture, and the ways in which cross-fertilization between the two fields could be achieved.<sup>85</sup> About the initial idea of *Circle*, Barbara says: "Early in 1935 the idea of publishing a book on constructive Art was born during an evening's conversation in our studio between J.L. Martin, Ben Nicholson, Naum Gabo, Sadie Speight, and myself. Work began on it almost at once."<sup>86</sup> Later in the summer of 1937, and as a reaction against the Surrealist Exhibition that took place in 1936, Ben, Barbara and Gabo met in a tearoom where, along with Leslie Martin and Sadie, they planned to develop further the idea of an exhibition, showing that Constructive art could soon transform the visual environment into a new era. About this meeting, Margaret Gardiner recalls a letter she received from Barbara:

*Circle* was, in fact, born in an ABC teashop where Barbara, Ben and Gabo had gone to restore themselves one day in 1936 after viewing the Surrealist Exhibition and where they decided that they absolutely had to do something to clear the air. Out of the teatime talk and of many later discussions with friends came the decision to produce a book of contributions from artists whose basis was the constructive trend in contemporary art [...] Gabo, Ben and their architect friend, Leslie Martin, undertook the editing and in 1937 this significant and influential book was published.<sup>87</sup>

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<sup>85</sup> Checkland, S. [2000]. *Ben Nicholson. The Vicious Circles of his life and art*. London: John Murray, 154.

<sup>86</sup> Hepworth, B. [1970]. *A Pictorial Autobiography*. New York: Praeger, 37.

<sup>87</sup> Gardiner, M. [1988]. *A Scatter of Memories*. London: Free Association Books, 185.

Indeed, in that autumn, the abstract team met at Martin's home, in Hull, working on a combined exhibition and publication of *Circle*, and one year after the Surrealist Exhibition, *Circle* was launched at the London Gallery in Cork Street.<sup>88</sup> Later, at the outbreak of war, Barbara and Ben moved to their home at St.Ives, Cornwall, and during this period many were the friends who regularly visited them, among others: Leslie Martin and Sadie Speight, Margaret Gardiner and Desmond Bernal, Solly Zuckerman, and the economist John Summerson, the historian Adrian Stokes and most of the artists of the Hampstead circle. It was due to the friendship between Zuckerman and Bernal that Bernal got to know Barbara Hepworth at her studio in Hampstead, an earlier encounter that proved to be pivotal in broadening the discussions between science and art. Margaret in her memoirs recalls: "I had taken Desmond Bernal to the studio to meet Barbara and he was immediately fascinated by her carvings, whilst she was fascinated by his explanations of their scientific and historical parallels."<sup>89</sup> It was during this period that Barbara approached Bernal, asking for a foreword for the catalogue of the exhibition that she was preparing:

Do you think you could possibly write a foreword to my Exhibition catalogue? [...] and if you could possibly manage to, it would of course be of the greatest help. All this sounds very personal, but actually it need not be so personal, it is really an opportunity to say a few words in support of an idea. You would of course have to come and look at the work! As there are at least 10 new carvings, which you have not seen<sup>90</sup> [Fig.11, 12].

In another letter to Bernal, Barbara says:

Dear Desmond, I am so sorry it was too late last night when you said what your idea of constructive art was. I really should be so interested to know exactly where you think your idea differs from ours [...] You always seem to me to be searching to discover and apply basic laws plus principles. Your criticism is most stimulating because you know exactly where a law has been broken and can apply the principle so that you can make the solution clear. [...] The biggest criticism that is ruled against construction art is that it is limiting, but it seems to me the freest possible thing.<sup>91</sup>

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Checkland, S. [2000]. *Ben Nicholson. The Vicious Circle of his Life & Art*, 166.

<sup>89</sup>

Gardiner, M. [1988]. *A Scatter of Memories*. London: Free Association Books, 174.

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Bernal Archive, Cambridge Library, Cambridge University.

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Bernal Archive, Cambridge Library, Cambridge University.

Barbara's exhibition took place at *Reid & Lefevre* Gallery, in October 1937, and Bernal did write the foreword to the catalogue. He stated:

This appreciation of the sculptures exhibited by Miss Hepworth is not to be taken as an aesthetic criticism. It simply expresses the relation of an extremely refined and pure art form to the sciences with which it has special affinities [...] Its geometrical character does in fact bring it immediately into relation with the developments of modern architecture. Its forms require to be combined integrally with those of buildings to which they would give completeness that is at present lacking.<sup>92</sup>

Much of this discussion was centered on the idea of constructive art, a theme that was already central in many of the *Circle* texts, and which was introduced by Gabo, in his manifesto of constructive art written in 1920 in the USSR. For Gabo and his followers, constructive art was a way to achieve simplicity through geometrical clearance of structure and material means. Somehow Gabo and Bernal represented the scientific view of art and it was during Bernal's stay in London that his contacts with architects and engineers started to be widened.<sup>93</sup> Moreover during 1935 Bernal and Lubetkin both lived in the same house in Gordon Square, not very far from Lubetkin's modern masterpiece, Highpoint I, located in North Hill, Highgate [Fig.4]. According to Lubetkin, Bernal used to browse through architectural magazines on Lubetkin's table, whereupon the two would discuss various issues related to modern architecture, structures and planning. Lubetkin wrote:

For a while in 1935 Bernal and I both lived in the same house in Gordon Square. However in occasions, Desmond Bernal visited me on the way down his den upstairs. Glancing at architectural periodicals on my table, he expressed concern about the prevailing dualistic approach to architecture.<sup>94</sup>

At the beginning of the war Bernal was more committed to the war affairs and, besides his Chair of physics at Birkbeck College, University of London, he was appointed to the Civil Defense Research Committee, with a full time job for the Ministry of Home Security. Both professional appointments would strengthen even more Bernal's commitment to research into the relationship between architecture and building science, something that would really come

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<sup>92</sup> Bernal, J. [1937, October]. *Catalogue of Sculpture by Barbara Hepworth*. Alex. Reid & Lefevre, LTD.

<sup>93</sup> After being appointed lecturer in Structural Crystallography, at the Cavendish Laboratory at the University of Cambridge, in 1927, Bernal moved to London where he would be a Professor of physics at Birkbeck College.

to the fore during the 40s and 50s. It was also at the eve of WWII that his relation with Margaret Gardiner, one of the genuine patrons of the Hampstead group<sup>95</sup>, had also come to an end. Since the late 20s that Bernal and Margaret shared much of an ideological belief, both visited the USSR in 1930, and nurtured a truly enjoyment for art. On a handwritten card Barbara writes to Bernal:

Dear Desmond, I saw Margaret and she told me you had separated. I am so sorry. I do hope though, that we us shall not lose sight of you. We should both be particularly pleased if you would come to see us, whenever you have time if you would care to. Best wishes, Barbara p.s do try to see Gabo's new construction, it is very fun, I think you' would like it as much as I do<sup>96</sup> [Fig.13].

While the effervescent atmosphere of art was centered on Cambridge and London, Leslie Martin, at the age of twenty-six, was appointed Head of the School of Architecture at Hull College of Art and Crafts. Although living in Hull, Leslie Martin and Sadie Speight were in close contact with the artists of the Hampstead circle, and as mentioned before soon started to collect works by artists such as Ben Nicholson, Barbara Hepworth and Naum Gabo.<sup>97</sup> During Martin's stay in Hull, 1934-1939, he made a great effort to bring the modernist architects and artists he had met before, to lecture to his students<sup>98</sup> and to public audiences at the City's *Ferens Art Gallery*.<sup>99</sup> Herbert Read, Morton Shand, Marcel Breuer, Serge Chermayeff, Maxwell Fry, Laszlo-MoholyNagy and Naum Gabo seem to have been regular visitors among others.<sup>100</sup>

#### 4.5 Industrial Design. The advent of modernism in the UK

The British Avant-garde represented much of a new epoch, an attitude which started to be embodied in art, but this new endeavour was not only in need of new protagonists, but was also lacking an institutional structure that could promote the modernist ideology, particularly

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<sup>94</sup> Letter from Lubetkin to Francis Aprahamian, 1983.

<sup>95</sup> Gardiner's outstanding collection of 20<sup>th</sup> art is at the museum that she founded at the Orkney Islands. *Pier Arts Centre*, Stromness. Scotland.

<sup>96</sup> Bernal Archive, Cambridge Library, Cambridge University.

<sup>97</sup> A relationship that would endure and that would lead Gabo to set up a studio at the Martins' future house and studio at the Mill, in Cambridgeshire.

<sup>98</sup> According to Peter Carolin, initially there were only four full-time students.

<sup>99</sup> The author contacted the *Ferens Art Gallery* inquiring for any documents [audio, video, articles, catalogues] regarding these public conferences, and according to the gallery's staff, there are no documents in their collections or archives that could illustrate those events.

in the field of industrial design. In the UK a common spirit of innateness in the mid-30s was in the air and was very much the consequence of the transformations that Industry and Art were facing at the beginning of the XX century in the UK. The demise of the Arts and Crafts movement and the urgency of bringing new design standards and technology to the design of everyday life objects, led ultimately to the establishment in 1919 of the Design and Industries Association [DIA] which, through a series of exhibitions, tried, even if not always successfully, to promote and show products designed and fabricated within a modernistic will. Most of these exhibitions took place in the mid-20s, a period when a lethargic Arts and Crafts Britain was casting about, without much conviction, for a new beginning.

By early in the second decade, the decline of traditional handicrafts, as a significant sector of the British economy, was more or less complete. Many of the Arts and Crafts societies faced bankruptcy and, in 1914, two influential former members of the Arts and Crafts movement visited the Deutscher Werkbund Exhibition in Cologne, a visit which was seminal to planting the idea to launch the DIA. Jack Pritchard who became DIA's chairman in 1933 would later give a full and historical explanatory view of what happened in Britain in those early days. He said:

In the early 20<sup>th</sup> Century we were sitting back, basking in the sun of our great wealth achieved during the industrial revolution, a rich and powerful plutocracy, smug and self-satisfied, believing that all was well: forgetting that it had no firm foundation, not understanding that it was based on a wasting asset founded on a series of fortuitous conditions - not repeatable. Britain in 1900 was almost 100 years behind France and Germany in providing education on a national scale that included science and technology. Even as late as 1913 there were still only 2,686 full-time students of engineering and technology in England and Wales as against a comparable figure for Germany of 11.000.<sup>101</sup>

This transitional moment was also eloquently expressed by the architecture critic Morton Shand:

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<sup>100</sup> The author contacted the Dean of the school of architecture in Hull, asking for any documents that could inform about the years that Leslie Martin stayed in Hull. No records exist to the present day.

<sup>101</sup> Pritchard, J. [1972]. "Must we make the same mistake twice?" *Year Book* of the Design and Industrial Association.

It is a melancholy and humiliating confession for an Englishman to make that the great movement towards standardization of design in terms of functional fitness, to which the genius of the German people is now applying itself, should find no echo in the country which initiated the Industrial Age. [...] The depressed state of British Industry and the progressive decline of our foreign markets are the direct result of innate conservatism, and refusal to live and work in the spirit of the present age.<sup>102</sup>

Despite the DIA's efforts to promote new standardized designs in Britain, it was not until the late 20s that the modernist spirit started to emerge more vigorously. This new attitude was achieved due to the endeavour and expertise of a group of talented architects, designers and entrepreneurs who ignited the arrival of modernism. Serge Chermayeff, by marrying Barbara May [the daughter of the director of the London building firm, 'Holland, Hannen and Cubits'], entered a circle which allowed him to carry out a series of ventures related to the promotion of a new aesthetic culture. On behalf of Chermayeff, the chairman of 'Holland, Hannen and Cubits', J. B. Stevenson approached Lord Waring, the chairman of 'Waring and Gillow,' one of the leading names in furniture design, interiors and ocean-liner design in London, suggesting Chermayeff as the person who could introduce new designs into the firm. Through this connection Chermayeff was appointed Director of the Modern Art Design Studio and Department at 'Waring and Gillow' and soon after organized one of the first exhibitions to introduce newly designed objects to the London scene. Working for 'Waring and Gillow' provided Chermayeff with a springboard for his career, and he became one of the best-known young designers in London. Chermayeff was responsible for the exhibition of 'Modern Art in French and English Furniture and Decoration' at the 'Waring and Gillow' shop in Oxford St, London, in November 1928. In the opening speech of the exhibition, Chermayeff said:

You have seen, or you will be able to see, on the fourth floor, the collection of works which I have created at the request of Lord Waring, especially for the educated of the English public: I hope that they will speak to you for themselves and I will therefore not refer to them specifically. I desire simply to say that this Exhibition appears at an appropriate time and I will give you my reasons as briefly as possible.<sup>103</sup>

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<sup>102</sup> Shand, P. [1930]. "Type forms in Great Britain," *Die Form*, Jahrgang 5, 312.  
<sup>103</sup> Serge Chermayeff Archive, Avery Library, Columbia University. NY, NY.

The urgent need to re-evaluate how design was conceived and produced was eloquently described by Chermayeff in another speech he gave at the 'Design in Industry, Design in Decoration and Furniture', at the DIA. Chermayeff said:

Mr. Gloag spoke to you last week about design in industry generally, and pointed out the ridiculous forms we meet in all walks of everyday life. Since listening to him you may have observed for yourselves the absurdities of some of the Gothic petrol-pumps in your own town or the Tudor radio-sets in your neighbours' homes. Already you may have done your best to lay the ghost-horse running before your car. Tonight I want to bring a little closer to you personally the importance of good logical design.<sup>104</sup>

Aiming towards broadening their knowledge on standardized production, Chermayeff, Pritchard and Coates visited in 1931 the Bauhaus in Dessau. The emphasis on the interaction between technology and art significantly impressed them and two years later the 'Exhibition of British Industrial Art' at Dorland Hall, organized by Roger Fry in 1933, was the best example for the public display of this new industrial art.<sup>105</sup> It was at this exhibition that Wells Coates' 'Minimum Flat', designed for Jack and Molly Pritchard was on display. During the mid-thirties a series of other exhibitions took place, and whatever the quality or degree of success, a new sense of phenomena relating design and industry gradually started to grow. Herbert Read's *Art and Industry* [1934] became the epitome of a new generation that was endeavouring to bring to British culture a view of what was already happening in a more advanced Europe.

Regardless of the importance of Chermayeff, Coates and Lubetkin in introducing modernism to the UK, much of the success of their enterprise was also due to Jack Pritchard, a Cambridge economist and engineer, who, leaving Cambridge in 1922 to learn scientific management, would join the 'Venesta' Plywood Company. 'Venesta's' main business was buying and selling different plywood mills in the Baltic, and it was associated with 'Luterna', another company which developed a new method for packing tea, as it was found that plywood was the most appropriate material. The bending of plywood, which started to be mastered in many of the designs that Pritchard's company 'Isokon'<sup>106</sup> was producing, was already being developed at 'Luterna's' factory in Tallin, Estonia, which was also producing

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<sup>104</sup>

Ibid.

<sup>105</sup>

See review. [1933, June]. "The Exhibition at Dorland Hall," *Design for Today*, 74.

seats for tram-cars made of plywood [5 or 6 feet long] and fabricated in many different profiles. Two of the factories were located in Helsinki and Lojo, Finland and in August 1935, Pritchard made a visit to Finland with Morton Shand and Graham Reid, director of 'Venesta', an occasion for Alvar Aalto to show them his Paimio sanatorium and the workshops where his own furniture 'Finmar' was being manufactured. This proved a successful journey, as Venesta and later 'Isokon' were able to fabricate extraordinary design pieces, many of them design by Gropius and Breuer while their stay in UK.<sup>107</sup>

#### 4.6 The formation of a new architecture culture

In 1931, Virginia Woolf, published *The Waves*, a novel telling the breathtaking history of the life of six characters by revealing their thoughts and associations. Solly Zuckerman, who acknowledged the importance of Virginia's novel by that time, could be one of the fictional personages that so brilliantly Woolf as described and the interplay of people that by the early 30s were forging much of the artistic ideas in Cambridge and London could also constitute a vivid scenario to *The Waves*.

The formation of a new architecture culture was thus influenced by the contacts between different personages of the British avant-garde and due to an acute sense of the use of technology and of science. If on the one hand Chermayeff and Lubetkin have played an important role in the transformation of British architecture due to their technical expertise's, on the other, Coates owing to his genuine fascination with science also had a major influence in the formation of this new architectural attitude. Coates, who would become the leader of the Modern Architecture Research Group in 1933 [MARS] and chief of the British delegation to CIAM, was born in Japan, served as a pilot during WWI, and completed his studies at McGill University, in Canada, with a degree in Structural and Mechanical Engineering. Coates's lifelong attention in motorcars and airplanes was part of a wider interest in technical and mechanical processes, setting him apart from other colleagues, whose architectural training had been conventional and art- oriented.

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<sup>106</sup> 'Isokon', founded in 1931.

<sup>107</sup> Before getting to know Alvar Aalto, Pritchard, who worked for Venesta in Paris [1929-30], had already visited Corbusier's works, met Lubetkin, and with the help of John Gloag, who was working for an advertising agency employed by Venesta, invited Le Corbusier to design an exhibition stand for Venesta for the Building Trades Exhibition, held at Olympia in September 1930.

In 1922 went as a PhD student to London University<sup>108</sup> and if his work did not lead to a career in science, it provided a process of thought that allowed Coates to be intellectually above most of his colleagues. Coates believed that it was by bringing Art and Science together in architecture that architects would find a meaningful professional path.<sup>109</sup>

By the late twenties, when the major built architecture still reflected a predominantly European half-modernism, Wells Coates was already trying to establish his architectural practice in London<sup>110</sup>, a time when the premises of modernism were barely known in the UK. By then Frederick Etchell's translation of *Vers Une Architecture* in 1927 was the first notable literary presentation of the most advanced theories of architecture in Great Britain, and despite this and a few other articles advertising the architecture of the modern movement,<sup>111</sup> the general architectural atmosphere of that period was still too premature to hail the emergence of a consistent new modern spirit. As mentioned before, Serge Chermayeff and Berthold Lubetkin had particular technical skills, and if we add the expertise and creativity of Ove Arup,<sup>112</sup> the scientific and critical views points of Desmond Bernal, the constructive thought of Naum Gabo, the experience of Walter Gropius, the entrepreneurship of Jack Pritchard, and the academic vision of Leslie Martin, we can envisage the richness of an intellectual milieu that promoted the formation of a new architecture culture, one that not only allowed the construction of some modern masterpieces, but which also fostered a culture of scientific investigation within architecture and practice.

It is interesting to note that the most innovative architectural works of this time, early 30s, came out of the acquaintances between the Cambridge and Hampstead group and how the Huxley family played an important role in the genesis of this endeavor. Aldous and Julien Huxley were the grandsons of Thomas Henry Huxley, Darwin 's colleague; whose work *On*

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<sup>108</sup> *The Gas Temperature of the Diesel Cycle* was his PhD dissertation. The most accurate study of Wells Coates is the PhD thesis by Farouk Hafiz Elgohary: *Wells Coates and his position in the beginning of the Modern Movement in England*. University of London, 1965.

<sup>109</sup> His interest in science is well demonstrated in a series of articles written when he was a science correspondent in London. In a brief period of 3 months Coates wrote about the discovery of x-rays, a revolutionary process of converting raw rubber into commercial goods, converting fog into rain in Hong Kong, and an article about the theory of relativity.

<sup>110</sup> See interview with Wells Coates: "Modern Dwellings for Modern Needs," in, *The Listener* [1933, 24 May], 818-22.

<sup>111</sup> Scheffauer, H. [1924, December]. "The Work of Walter Gropius," *The Architectural Review*. Vol. LVI., 50-54. A first general survey of Russian Constructivism published in 1932 by Lubetkin. See: Lubetkin, B. [1932, May]. "Architectural Thought since the Revolution," *The Architectural Review*, 173-214.

<sup>112</sup> Whose first degree was in philosophy.

*Science and Art in Relation to Education*<sup>113</sup> had already opened the discussion about the place of science and art in society.

Julian Huxley, Aldous brother, was Professor of Zoology at Kings College and was about to resign his position as Anatomical Research Fellow at the Zoological Society. Zuckerman who had met Julian at the 'Heretics Club' in Cambridge, was then chosen to take his place till 1932. The Prosectorship of the Zoological Society was a prestigious position that was established in mid-Victorian times by T.H. Huxley, one of the foremost biologists of the period and Zuckerman friendship with Julian Huxley, brought him to a universe of science that went beyond that of the University environment. It was through the public lectures that Zuckerman was being invited to give, that he met important figures of the contemporary cultural and scientific milieu of London and Cambridge.

Out of the network of relationships of this period, one of the first and major modern buildings in London appeared: The Gorilla House, at the London Zoo, by Lubetkin, which opened in 1933, [Fig.5, 5a] and commissioned by Julien Huxley, shows how interwoven were the contacts of that period. Solly Zuckerman, after obtaining the position of Prosecutor at the London Zoo, met Barbara Hepworth, Ben Nicholson, and Henry Moore, and from that moment on spent hours in their studios in Belsize Park, north of Regent's Park. The Zoo through its scientific meetings was a source of social gatherings and in one of those occasions, Zuckerman met Philip D'Arcy Hart's cousins [Godfrey Samuel] who had recently graduated from the Architectural Association, London, and who soon after would join *Tecton*, the new architecture office established by Berthold Lubetkin.<sup>114</sup> It was through Zuckerman, and Samuel that the ideas of designing a house for the two new gorillas that the Zoo had acquired arise. This was the beginning of the Gorilla house project in Regent's park by *Tecton*. After the completion of this building, Lubetkin designed the Zoo's famous Penguin Pool [1934], [Fig. 6, 6a] and the Elephant house at Whipsnade [1935].

However, the success enjoyed by *Tecton* was an exception that could not be generalized in the thirties. The lack of work and the difficulty in obtaining commissions in Great Britain led Walter Gropius and Marcel Breuer to accept a partnership with Pritchard's new *Isokon* Furniture Company, where they were respectively the Design Controller and the Chief Designer. During this period, the furniture that Gropius and Breuer designed for 'Isokon', and

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<sup>113</sup> Huxley, T. [1882]. "On Science and Art in Relation to Education," *Collected Essays III*.

<sup>114</sup> *Tecton* formed in 1932 with Chitty, Drake, Dugdale, Harding, Samuel and Skinner.

the advertisements created by Naum Gabo, were manifestations of a new culture of design that achieved in the Lawn Road Flats its most successful expression by integrating different arts within a modern architectural belief [Fig. 7,7a]. During this period Gropius formed a partnership with the architect Maxwell Fry, which led to Gropius's only public building in Britain, the Impington Village College, in Cambridgeshire. Marcel Breuer formed a partnership with F.R.Yorke, and from 1935 to 1937, Erich Mendelsohn joined Chermayeff in what became their joint venture, designing and constructing the De La Warr Pavilion, at Bexhill-on-Sea, in 1935. However this enterprise came symbolically to an end by the occasion of Gropius departure from England for the USA. The farewell Gropius dinner took place on March 9<sup>th</sup> 1937, [Fig. 16] and represents the end of a transitory period. From now onwards England will face the drastic consequences of war and will have to put in practice and at a larger scale many of the beliefs and technical expertise gained during the 20s and 30s.

**CHAPTER 5** Desmond Bernal. The Interwar period and the foundation of LUBFS

*The present situation, where a highly developed science stands almost isolated from a traditional literary culture is altogether anomalous and cannot last*

Desmond Bernal

## 5.1 The Necessity of Planning and the Organization of Building Research

Before WWI, British architecture was still on the edge of the Post-Industrial era; lack of housing and a desolate image of suburbia were what characterized the urban environment of the late 20s in Great Britain and the need for new housing and town planning showed the misfit between architectural training, [both technical and theoretical], and the new demand for processes and building techniques. It was estimated that by the mid teens only 5% of dwellings in the UK had been built by local authorities<sup>115</sup>, and that by the end of the war, 100.000 new houses would be needed each year due to the increasing population and the urgency of housing replacement. Moreover, the 1911 census showed that there were eight hundred thousand more families than dwellings; that one-tenth of the population lived in grossly overcrowded conditions, more than two a room, and that in some of the big towns the proportion was as high as one-third.<sup>116</sup> The almost total lack of investment and of research into construction systems since the early days of the Industrial Revolution contributed to this scenario.

The housing situation during the war period was thus problematic: no new houses had been built, there was a shortage of small houses, and the cost of building was extremely high. As a means to change this, a strategy that could inform the implementation of new policies for new settlements had to be devised. In the late teens, the Department of Scientific and Industrial Research [DSIR] was founded to increase the sponsoring of state research in partnership with industry. In this endeavor the architect and city planner Raymond Unwin [1863-1940], who would later become the president of the Royal Institute of Architects [RIBA]<sup>117</sup>, was the pioneer of a new approach to the problem of housing and planning. Unwin, influenced by Ebenezer Howard's *Garden Cities of Tomorrow*<sup>118</sup>, applied geometry and mathematics to the study of urban densities as a way to advance a new methodology in urban planning, and as an innovative approach to promote the growth of scientific spirit in the building industry. As a response to Unwin's demands for new legislation on residential standards, in 1890, the London County Council [LCC] became one of the first government offices able to control, execute, and supervise work in the domain of public housing and planning. By then the 'First

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<sup>115</sup> Evens, P. [1976]. "Raymond Unwin and the Municipalisation of the Garden City." *Transactions of the Martin Centre for Architectural & Urban Studies*. [Vol 1, 252]. Cambridge, MA: University of Cambridge. See also: Smith, M. [1971]. "A Guide to Housing" London: Housing Centre Trust.

<sup>116</sup> Reiss, L. [1933, January 25]. "Housing-the Last Decade and the Next," *The Listener*, 132.

<sup>117</sup> Raymond Unwin, RIBA president between 1931 and 1933.

<sup>118</sup> Howard, E. [1945]. *Garden Cities of Tomorrow*. London: Faber and Faber. First published in 1898 under title: *Tomorrow, a peaceful path to real reform*.

Housing and Town Planning Act' was passed by government authorities in 1909. This made it possible to regulate plans for suburban developments and, soon after, the '1919 Housing Act' made the Ministry of Health responsible for housing policies and public health. Unwin was appointed Chief Housing Architect at the Ministry of Health, and investigation that would later be developed in the field of building science and architecture started to be sponsored by the Ministry of Health and by the Ministry of Building and Public Works. These policies were feature in daily news:

If Parliament had not helped, no new working-class houses would have been built. Or, if they had, the rents would have been much too high for working people to afford. So Housing Acts were passed which gave grants or subsidies from taxes and rates to help to keep down the rents of houses to be let at weekly rents. [...] Since 1919 great efforts have been made to improve living conditions.<sup>119</sup>

Despite the implementation of new policies, the urban form did not change greatly, and with the advent of WWII, Great Britain would again be facing a deplorable housing and planning crisis. Reviewing the history of British built environment since 1945, the architect Jack Napper affirms: "Apart from new housing suburbs of the 1920s and 1930s, virtually nothing had been spent on urban expansion and renewal for sixty years."<sup>120</sup> The urban landscape after WWII became one of desolation: "Masses of absolutely, decrepit buildings of depressing monotony were ranged along traffic streets. Low rise, high density and mortar,"<sup>121</sup> or as Dean Hawkes put it: "an undisciplined suburban sprawl of traditionally constructed, semi-detached houses."<sup>122</sup> After the war, the reorganization and the rebuilding of the suburban landscape became a priority issue, and new efforts to implement research guidelines at the level of planning and building were made at the newly formed Building Research Station [BRS], and at various scientific committees. Later, in the mid-60s Lionel March and Leslie Martin carried out a series of studies that addressed planning issues and the use of land and of built form.

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<sup>119</sup> Reiss, L. [1933, January 25]. "Housing-the Last Decade and the Next," *The Listener*, 132-3.

<sup>120</sup> Napper, J. [1975, November-December]. "The long Week-End," *RIBA Journal*, 26-32.

<sup>121</sup> Ibid.

<sup>122</sup> Hawkes, D. [1976]. "Garden Cities and New Methods of Construction. Raymond Unwin's influence on English housing practice" In, Philip Steadman & Janet Owers [eds.], *Transactions of the Martin Centre for Architectural & Urban Studies* [Vol 1. 275-96]. Cambridge: University of Cambridge.

Martin asked:

How does the grid affect possible building arrangements? Which building arrangements appear to make the best use of land? If certain patterns of buildings are more advantageous in their use of land, then it is important to understand the principles behind this.<sup>123</sup>

Looking at the correlation of residential building forms to densities, and by developing systematic studies of measurable factors and their interrelationships,<sup>124 125</sup> March and Martin were hoping to develop a more general theory that could be applied to different urban contexts. This would be one of the areas of research at LUBFS.

## 5.2 Desmond Bernal. Science, War and Air Raid Precautions

John Desmond Bernal was a young Irishman, the son of Samuel Bernal, a Sephardic Jew and of Elizabeth Miller, the daughter of an Irish Presbyterian clergyman. His father, Samuel emigrated to Australia in 1884 at the age of 15 to work on a sheep farm, and fourteen years later returned to Ireland and met his future wife, Elizabeth [Bessie] Miller, an educated American woman who had studied at Stanford University, USA, and at the Sorbonne in Paris. Bernal, the eldest of the couple's three sons, was born in 1901, on the farm of Brookwatson, near Nenagh in Country Tipperary and after a catholic education moved to Cambridge in 1919 to study mathematics at Emmanuel College. This was the beginning of an education and career in science that would make Bernal one of the most influential scientists of his time. Being the same generation, Desmond Bernal and Leslie Martin had many friends in common. Martin was born in 1908 and was educated in an aristocratic environment that would influence his future social and professional acquaintances. His father, Robert Martin, married to Emily, was a respected architect in Manchester, the city where Martin graduated in architecture and gained his PhD at the early age of 26.

Bernal and Martin, who probably first met at the 'Abstract and Concrete Exhibition' in London in 1933, actively participated in the cultural and social events that went with their professional careers. Although we do not know how close they were we know that both enthusiastically

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<sup>123</sup> Martin, L. [1968, 15 February]. "City Patterns," *The Listener*.

<sup>124</sup> See: March, L. [1967, August]. "Homes Beyond the Fringe," *RIBA Journal*,

<sup>125</sup> See: Martin, L and March, L. [1966, April]. "Land Use and Built Form Studies," *Cambridge Research*, [2/6], 8-14.

contributed in the production of *Circle*, and took part in several architecture research meetings, mainly the Architecture Science Group [ASG] within RIBA, in London. During this period, Bernal was at the center of almost every scientific, social and cultural activity that took place on the London and Cambridge scene, and his incredible knowledge on an infinite variety of subjects led his friends to call him 'Sage.' This insatiable thirst for knowledge favored his friendship with many distinguished scientists and artists, and it was through Solly Zuckerman and Margaret Gardiner that Bernal started to be in contact with the current ideas on modern architecture.<sup>126</sup> However, his involvement and interest started much earlier, as his seminal and remarkable book *The World, the Flesh and the Devil*<sup>127</sup> illustrates. Written and published when Bernal was 28 years old, it shows a concern for environmental issues on a global scale, ideas about the development of new materials through the possibilities of changing the molecule level of materials. Bernal says:

The physical discoveries of the last twenty-five years must find their application in the world of action – a process which has hardly begun, but the nature of which can easily be seen. It should lead to a development of new materials and new processes in which physics, chemistry and mechanics will be intractably fused. The stage should be reached in materials when they can be produced not merely as modifications of what nature has given us [...] but will be made to specifications of a molecular architecture. Already we know all varieties of atoms; we are beginning to know the forces that bind them together; soon we shall be putting them together in a way to suit our own purposes.<sup>128</sup>

This astonishing view of atomic procedures [nanotechnology],<sup>129</sup> which would allow the creation of new materials and structures, is not so strange if we acknowledge Bernal's reputation as a physicist and molecular biologist. At this time, Bernal was elected Fellow of the Royal Society, appointed to the Chair of Physics at Birkbeck College, University of London, and conducted pioneer research in X-ray crystallography, which led him to become a

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<sup>126</sup> Particularly relevant were the contacts that Bernal established with Berthold Lubetkin, Wells Coates and Ove Arup.

<sup>127</sup> Bernal, D. [1969]. *The World, the Flesh and the Devil. An Enquiry into the Future of the Three Enemies of the Rational Soul*. London: Indiana University Press. [1<sup>st</sup>. edition, 1929]

<sup>128</sup> Bernal, D. [1969]. *The World, the Flesh and the Devil. An Enquiry into the Future of the Three Enemies of the Rational Soul*. London: Indiana University Press, 5.

<sup>129</sup> This account of nanotechnology precedes in 30 years Richard Feynman's famous talk, "There is enough Room at the Bottom" given on December 29th 1959 at the annual meeting of the American Physical Society at the California Institute of Technology [Caltech] and first published in the February 1960 issue of Caltech's *Engineering and Science*.

leading figure in molecular biology and genetics.<sup>130 131</sup> It was indeed Bernal who first brought architecture into the field of research, relating it with science. In 1937 at the age of 36, Bernal published his first article in the *RIBA Journal*. In this article Bernal pointed out:

The academic architect and the academic scientist were poles apart. The result has been unhappy for both sides. The essential superficiality that marked the decay of architecture in the nineteenth century and still marks school architecture today is due to a preoccupation with the appearance rather than structure or function.<sup>132</sup>

This concern about the conflict between art and science was a constant in Bernal's thoughts and was the chosen topic for his next article, "Art and the Scientist"<sup>133</sup> published in *Circle*, which stressed the need to fuse these disciplinary fields of the arts and of the sciences.

If Bernal's first book represented the speculative creativity of a young scientist, his second, *The Social Function of Science*,<sup>134</sup> embodied on the one hand a broad set of concerns regarding the relationship between science, art and society, and on the other, a preoccupation with the making of science policies and with the use of technology. Again, Bernal was the first to see science as a social subsystem, as cultural phenomena, and the first to attempt to define its boundaries, and to try to relate these issues to a global political and social system both in its historical development and in future strategies.<sup>135</sup> Bernal's book, which was a successful attempt to bring science and its disciplines into the realm of public debate, was divided into two large sections: 'What Science Does' and 'What Science Could Do', each reviewing in detail the political problems of the planning of science and the allocation of resources to various branches of organized R&D in the UK and matters such as building science, energy issues, material research, town planning and housing were also closely analyzed.<sup>136 137</sup>

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<sup>130</sup> Later, Bernal's group constituted 'The Biomolecular Research Laboratory' at Birkbeck College, which was officially opened on 1<sup>st</sup> July 1948 by Sir Lawrence Bragg, with whom Bernal worked earlier after finishing his studies in Cambridge.

<sup>131</sup> Two of Bernal's students, Dorothy Crowfoot Hodgkin and Max Perutz went on to become Nobel Laureates.

<sup>132</sup> Bernal, J. [1937] "Architecture and Science," *RIBA Journal*, 805-12.

<sup>133</sup> Bernal's article in *Circle*. 1937.

<sup>134</sup> Bernal, J. [1939]. *The Social Function of Science*. Cambridge: The MIT Press.

<sup>135</sup> Bernal's interest in history led to a further book, Bernal, J. [1954]. *Science in History*, London: C.A.Watts.

<sup>136</sup> Bernal, J. [1939]. *The Social Function of Science*. Cambridge: The MIT Press, 350-3.

<sup>137</sup> Given the importance of the subject, Bobby Carter, RIBA's librarian, wrote a review of the book for the Architectural Association magazine, *FOCUS*. He remarked: "In our own field of building or science it is deplorable that there is not a single chair of building or architectural research in its full meaning in any university. [...] As far as our schools of architecture are concerned as a forcing ground for a profession aware of the problem, we are

This aim to bring science into the public domain, and the need to involve science and scientists in warfare, was at the forefront of Bernal's concerns. During the mid-30s the political situation in Europe and in particular in the UK, started to deteriorate, and a general concern regarding the possibility of aerial attacks started to emerge. This fear was also greatly deepened due to the lack of reasonable public and government discussions on the problem of air-raid precautions [ARP]. To overcome this situation, scientists from different fields started to conduct rigorous surveys concerning the logistics of civil defense and forecasts about the degree of destruction that cities would face in case of enemy attacks by air. In 1937 the Cambridge Scientific Anti War Group, [CSAWG], published *The Protection of the Public from Aerial Attack* with details of measurements and actual experiments with bombs. Bernal wrote a description of the CSAWAG's early work:

Some scientists at Cambridge formed the anti-war group. We studied poison gases and protection against them. We saw that, in the event of war, science would have to play a big part in it. What we wanted to ensure was that, in the first place, the people would get a sufficiently clear grasp of the dangers they were running into and that they would unite to prevent war. But for that there was not enough goodwill in time.<sup>138</sup>

In the following year, the Council of the Metropolitan Borough of Finsbury, London, contacted *Tecton* asking for a recommendation on the suitability of available public basements for use as civic shelters. These requests led to the development of studies by *Tecton* on existing shelters where aspects such as accessibility, space accommodation, evacuation time, electrical and ventilation supplies were taken into consideration. Furthermore, technical features such as the effect of bombs on the sidewalls of shelters and surrounding constructions and on their superstructure were also analysed. These initial premises soon showed that decisions as to whether to keep existing basements as war shelters or whether some other form of shelters could be thought of, would have to take place. These and other matters concerned with civil defense started to be expressed in a monthly publication called *Air Raid Defence*, the official publication of the 'Air Raid Defence League', which was an independent organization that wanted firstly to make public a cross-section of opinions

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still tied to a system which evolved as a reaction from the hit-and-miss empiricism of articulated pupillage rather than as a response to any coherent plan." Carter, E. [1939]. *FOCUS*, 38-42.

<sup>138</sup> Elga Kern, ed., [1956]. *Wegweiser in der Zeitwende*, Munich/Basel.

regarding war defense matters, and secondly to publish an examination of shelter needs. The first bulletin is clear in this regard:<sup>139</sup>

Faced with the need for adapting themselves to the prospect of heavy and indiscriminate aerial bombardment, the British people are naturally in urgent need of guidance. What are the dangers likely to arise in case of war? What should be the objectives of civil defense? What are the best methods of protecting the people and of maintaining the fullest wartime effort? On these and many other questions there is a great lack of concise, well informed, balanced and unbiased material.<sup>140</sup>

It was within this context that the technical work pursued by *Tecton* with Chermayeff took place. The initial results of their research conducted with the Borough Engineer and with Ove Arup, were first presented as a memorandum to the Finsbury Borough Council on October 4<sup>th</sup>, 1938, with a more extensive study presented as a report to the Council on February 4<sup>th</sup>, 1939. This report, which was later sent to the Home Office on February 6<sup>th</sup>, had two parts, the first dealing with structural aspects of shelters and the second with the application of a protection scheme to the Borough of Finsbury. The conclusions of this research, which were published as *Planned A.R.P.* by *Tecton*,<sup>141</sup> underlined the lack of known information concerned with “the penetrative and explosive effects of aerial bombs.” Their report states:

The collection of any exact data as to the effects of bomb explosions is necessarily a very difficult matter, not only because any study comes near to touching on military secrets, since the bombs in use in foreign countries are not necessarily the same as those favoured here, but also because it is extremely difficult to predict with any degree of accuracy what will be the effect of a particular bomb. [...] In the same way as in other branches of scientific research, it would, of course, be possible, on the basis of a series of tests, to establish the effect of bombs on various structures, and from this to formulate conclusions as to the comparative protection given by various types of shelters.<sup>142</sup>

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<sup>139</sup> The initial issues of the League bulletin covered the following matters: “The Shelter Problem”, “An Outline of Civil Defence”, “The Nature of the Air Threat” and “Evacuation.”

<sup>140</sup> *AIR RAID Defense*. Volume I, March 1939, 1.

<sup>141</sup> *Planned A.R.P. Based on the investigation of structural protection against air attack in the Metropolitan Borough of Finsbury*. [1941]. New York: Chemical Publishing Company, Inc. [UK edition, 1939].

At this stage Bernal assumed a crucial role. He and Zuckerman were the leading scientists doing tests and calculations which provided detailed information as to the nature and effects of air-raid attacks. This was a collaborative work between Bernal, the *Tecton* architects and Ove Arup, who would design a new solution for a shelter. The 'Multi-Storey Bomb-Proof Shelter' as it was called, was a circular geometrical figure which had greater resistance to the pressure exerted by the explosion of bombs outside it. "A cylinder sunk into the ground", several storeys in height, "this is in essence a shelter design which was evolved by Mr. Arup, in conjunction with the authors, for the Borough of Finsbury"<sup>143</sup> [Fig. 17]. In the same year, 1939, Serge Chermayeff published *Plan for A.R.P. A Practical Policy for Air-Raid Precautions*,<sup>144</sup> and the foreword of this publication, which also received the contribution of Bernal and the M.A.R.S. group, mentioned:

This Memorandum is an attempt to draw together in a systematic form all that has so far been established scientifically and technically about the subject of air-raid protection. There are very few of those competent to judge who will not agree with all its main conclusions; and there are many hundreds of experts in diverse fields of science and technology who will welcome its publication, because it gives them their basic material for future work.<sup>145</sup> [Fig. 18].

Since the outset of the war, Bernal had been involved in the Research and Experiments Department of the Ministry of Home Security, then housed at the Forest Products Research Station at Princes Risborough, only 20 miles from Oxford, where Zuckerman was lecturing in Zoology. It was Sir Reginald Stradling, the director of the Building Research Station [BRS], who, appointed Scientific Adviser to the Ministry of Works and Chief Scientific Adviser on civil defense, started setting up the Princes Risborough Research Station. Despite Bernal's left-wing ideological affiliations, Stradling still commented that he wanted Bernal as an additional adviser on civil defense,<sup>146</sup> and so Bernal and Zuckerman started to form a new research team and to produce from scratch a research programme in which emphasis was put on statistics and mathematical modelling. New maths had now to be used to handle large amounts of data, and Bernal was responsible for bringing a mathematician and lecturer,

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<sup>142</sup> Ibid., 12.

<sup>143</sup> Ibid., 77.

<sup>144</sup> Chermayeff, S. [1939]. *Plan for A.R.P. A Practical Policy for Air-Raid Precautions*. London: Frederick Muller, Ltd.

<sup>145</sup> Serge Chermayeff Archive, Avery Archive, Columbia University. NY.NY.

<sup>146</sup> Zuckerman, S. [1978]. *From Apes to Warlords, 1904-46*. London: Hamilton. London, 103.

Jacob Bronowski, from Hull University College to help with the program. Soon Bernal, as team leader of the Civil Defence Research Committee, was in despair at the lack of valid information on warfare data, and in particular at the lack of information regarding the behaviour of explosives. He therefore launched himself into the physics of explosions, measurements of resistance of structures to different types of shock, and the effect of shock waves on the living body.<sup>147</sup>

His opinion was shared with all those who were at the dinner of the 'The Tots and Quots' Club in Cambridge, on 23 November 1939. Bernal opened the discussion on the theme of the use of science in wartime industry, a theme that Bernal and Zuckerman discussed further on a trip to France with the objective of seeing what British civil defense research could learn from French military experts. Comparing data with French specialists, Bernal soon realized how little exchange of information there was between allies. In one of the following dinners at the Tots,<sup>148</sup> Bernal stressed again the new need for a reorganization of science for war, and due to the presence of Allen Lane, the publisher of Penguin Books, it was agreed that their discussion would be published in book format. *Science in War*<sup>149</sup> was a publishing triumph and the twenty-five anonymous contributors helped to promote public debate and political awareness of the issues discussed. However the government response to these efforts was not very positive as a letter by Mr. Churchill clearly points out [Fig. 19]. The work of Bernal and Zuckerman on warfare continued until mid-1941, and both were recognized as the country's leading experts on the effects of bombs and other wartime issues.

### 5.3 The establishment of research in building science and architecture

The interwar period in the UK aroused debate on matters such as planning, housing, the use of land with the built form, and in applied research in architecture and building science, themes that would acquire a wider relevance during the 50s and 60s. The necessity of War reconstruction and the lack of scientific planning, housing and building research led to

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<sup>147</sup> In order to conduct field experiments Zuckerman took, in October 1939, a few of his monkeys for a series of tests on the effects of ground shock on various kinds of trench. The discoveries and conclusions of these research experiments were published as: *Science at War* prepared by J.G.Crowther and R. Whiddington [HM Stationary Office, 1974].

<sup>148</sup> Dinner on 12 June 1940.

<sup>149</sup> *Science in War*, was a sequel to: Haldane. J.B.[1941]. *Science in Peace and War*. London: Lawrence & Wishart Ltd. [ first published 1940. Reprinted 1941].

Governmental organization of building research in the UK.<sup>150</sup> The two major groups which contributed to the development of building sciences could be classified as follows: the Department for Scientific and Industrial Research [DSIR], and the Industrial Research Association, operating in close relationship with local industries and Universities. The focus of the DSIR on the building industry was through the Building Research Station [BRS]. Established in the aftermath of WWI, the BRS conducted research into the physical, chemical and engineering properties of building materials and structures. This was one of the several laboratories set up by the new Department of Scientific and Industrial Research. Here physicists were formally associated with architects for studies on the architectural problems of lighting, heating, and acoustics. One of its main duties was to try to set up material and constructions standards, a task that could not be performed without adequate discussion among the different groups of experts. This became one of the tasks of the Post-War study Committees formed under the supervision of the Ministry of Works.

Other Government Departments with responsibilities for building were the Ministry of Health [MOH], and the Ministry of Works [MOW], which would subsidize much of the research that would be carried out at the LUBFS. The Ministry of Works contained the Department of Chief Scientific Adviser, which would be in close contact with the various technical fields associated with building science. Moreover, associated to the BRS, was also the RIBA with its Architectural Science Committee [ASC], founded in 1937, the Architectural Science Board, established in 1939; and the RIBA's War Executive Group, all research groups dependent on RIBA's supervision. Sir Reginald Stradling, who became president of the BRS prior to the WWII, was responsible, as mentioned previously, for bringing Bernal into the Ministry of Works; an institutional relationship that developed Bernal's ideas through the various Governmental research centers. This involvement, which started in the mid-30s, allowed Bernal actively to participate in the various professional meetings of the Building Research Station, of the Royal Institute of British Architects, and of the Ministry of Works. In a letter to Chermayeff, Bernal ironically illustrates the political atmosphere between the Science Committee and the RIBA [Fig. 20]. This necessity of collaboration between different fields partly explains why Bernal published so extensively during the pre-and post-war period, with nearly 40 articles [including scientific reports] in several journals. In a special number of the

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<sup>150</sup> This is particular relevant as it stands in different context from US's policies. In the UK Governmental Institutions mainly sponsored research, in the US financial support came essentially from semi-private organizations.

*Architect's Journal* dedicated to Building Research in the UK, Bernal was invited to write the final and definitive section. Bernal pointed out:

By devoting one of its numbers to a general survey of science in building, the Architects' Journal has made a notable contribution to the better understanding between the architects and the scientists. The number of its papers and the wide range of subjects covered shows that the contacts between architecture and science have been recently – and particularly since the war – enormously increased and deepened [...] We are now in an intensely formative period, and consequently in a period when what matters most is that we should set off in the right direction and that we should all set off together [...] To carry it out, however, requires the fullest and closest co-operation between the scientists and the architect. In this the Architectural Science Board of the RIBA, which may reasonably claim to be the pilot organization for the comprehensive integration of science with building, may play a notable part. By its very existence it shows that the scientist and the architect are not rivals but colleagues, who have been too long parted and must come together effectively in the common task of building cities which will be worth living in.<sup>151</sup>

Bernal 's final remarks firmly illustrate a belief in multidisciplinary work, a faith that intellectual knowledge is not an enemy of beauty and of creativity but rather is a way of thinking. Besides his writings, Bernal was simultaneously invited to give public lectures at innumerable venues. Probably one of the most important lectures was the one he gave at the Northern Architectural Students' Association Congress of 1939, organized in Hull in the presence of many modernist architects and chaired by Leslie Martin [Fig. 21, 22, 23].

This was one of the important events that took place during Martin's leadership as Head of the School of Architecture. The symposium, 'Architecture, Science, Economics and Society' was attended by many modern architects who came to talk, and had two important sections: the first was the 'Symposium on Architecture,' with speeches by Serge Chermayeff, Desmond Bernal, E Roll, professor of economics at University College, Hull, and by Bobby Carter, librarian of the Royal Institute of British Architects and editor of the *RIBA Journal*; the second consisted of meetings of the council plus an exhibition of works by Walter Gropius and Marcel Breuer's students [School of Architecture, University of Harvard], and by the students of the School of Architecture in Hull. Serge Chermayeff, who was by then a

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<sup>151</sup> Bernal, J. [1946, November 28]. "Science and the Architect," *The Architects' Journal*, [104], 404-05.

respectable modern architect and on the eve of his move to the USA, mentioned the importance of applied research within architecture. He said:

The confusion as to the scope and aims of contemporary Architecture exists to the same extent in the profession, which divides itself into a number of people who are out of touch with contemporary developments in architecture, or are afraid of them or are simply incapable of grasping them. They become archaeologists or escapists, who prefer the ready-made culture of a known style to the more difficult task of research, experiment and definition of new aims.<sup>152</sup>

On the same occasion Chermayeff also pointed out: "Our second task, I think, is our own self-education through collaborative research with scientists and technicians working in every sphere."<sup>153</sup> After Chermayeff's discourse, Bernal who had just finished the publication of his *The Social Function of Science*, highlighted the urgent need for organized scientific research within the field of architecture. Bernal said:

What I am going to do in the few minutes available is to sketch in one of the aspects that Chermayeff mentioned, namely the part that scientific research has to play in this general programme for architecture. I mean science as a way of doing things, as a way of setting things out. This is a plea for the architect to go outside tradition in architecture and to find out what has been done in techniques.<sup>154</sup> [Fig. 24]

Further, regarding the necessity of planning, Bernal says, "The beginning rather than the end of architecture should be general planning research, in which the building is the last rather than the first point. You must first find the needs and then build for them [...] the need for research is as great, if not greater."<sup>155</sup> The correlation between material science research and architecture was very much highlighted at the Hull Symposium<sup>156</sup> and by the end of that same year, an Architectural Science Group was formed, bringing together the Building Research Station and RIBA's war executive group and two years later, in 1941, the Architectural Science Group was founded, acquiring an important place on the professional

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<sup>152</sup> Serge Chermayeff Archive, Avery Archive, Columbia University. NY,N.Y.

<sup>153</sup> Serge Chermayeff Archive, Avery Archive, Columbia University. NY, NY.

<sup>154</sup> Bernal Archive, Cambridge Library, Cambridge University. [Typed manuscript for the Northern Architectural Students Association Congress. Hull, 4<sup>th</sup> March. Symposium. Architecture, Science, Economics and Society].

<sup>155</sup> Ibid.

<sup>156</sup> See press coverage: "Young Architects Conference," *Daily Mail*, March 4, 1939.

side of architecture. Alister G. MacDonald who was the chairman of the ASG, writing to Godfrey Samuel and referring to the formation of the ASG, says: "I see that the A.A. is well represented. I am trying to get a date out of Prof. Bernal for a general meeting of the coordinating group and will let you know further."<sup>157</sup> The ASG was formed with five different committees: economics, education, planning & design, sociology, and a coordinating committee chaired by Bernal [Leslie Martin was working on the planning & design group] and in a later report on 'Research Organization in the Building Industry', Bernal defined the main categories according to which building research should be conducted. Five main areas were included: a) consumer needs, b) constructional planning c) structure, materials and building techniques, d) building organization, e) costs. Bernal gives a clear overview of how research in planning and architecture was being thought of. In a research Memo, Bernal points out the importance of the concept of "constructional Planning". He says:

Constructional Planning. This is properly speaking architectural research, the determination of the best choices of layout and materials required for types of buildings with different functions. So far this type of research has not been generally recognized, or rather, it has been left, as in other sciences 300 years ago, to the genius of the individual practitioners, though to some extent the Bauhaus at Dessau did attempt this task.<sup>158</sup>

Nevertheless, the profession had always neglected the introduction of scientific quantitative methods and this may have stood in the way of the acquisition of new skills and advances. Once again Bernal states quite clearly:

It is a common mistake to assume that the introduction of the scientific method into the field of design tends to cramp the imaginative powers of the designer. The reverse is true, for it is the supreme characteristic of the scientific outlook that it for ever looks forward.<sup>159</sup>

Later, as member and chairman of the Scientific Advisory Committee of the Ministry of Works, Bernal wrote:

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<sup>157</sup> RIBA Archive. SaG papers. Typed letter.

<sup>158</sup> Bernal, J. [1941, June]. "Note on Research Organization in the Building Industry," RIBA Archive. Architectural Library. SaG/99/2 papers.

The pre-war concept of building research as a technical matter of the examination of the performance of materials, essentially an extension of routine testing, has been replaced by a much wider concept. Research now includes general sociological and economic studies aimed at formulating in the first place the needs for building in such a way that the right technical problems are presented and then further research and development for solving those problems with full regard to the human and economic aspects of the building industry.<sup>160</sup>

Regarding planning issues, it is worth mentioning Bernal's position as it contains much of the spirit that would emerge at LUBFS. Bernal said:

Once planning becomes a science it does not cease to be an art. All that science does is to establish certain relations; we are still free within the limits that these relations impose to arrange things in a variety of ways. Not knowing what the limits are, or ignoring them does not give any freedom, it simply means that the results – and generally bad results – will be obtained contrary to the planners wishes. The more we understand about planning scientifically, the more the cities of the future will combine the characters of freedom and order.<sup>161</sup>

All these efforts to make research into practice an integral part of architecture and planning came to a conclusive public presentation. On 12 February 1946 Bernal presented a paper at RIBA entitled "Science in Architecture", a broad exposé of the changes that had taken place in the relationship between science and architecture, before and after the war. At this meeting, which was followed by a long discussion at the Architectural Science Board, Bernal summed up: "What I hope to do tonight is to show what a very large change has come over the relations of science to architecture in the last few years, particularly as a result of the war experience."<sup>162</sup> [Fig. 25]

The pragmatics of enhancing building science studies related to architecture, especially to housing, led the Ministry of Works and its Scientific Advisory Committee to conduct a series of surveys on new experimental housing schemes. During the late thirties, Bernal's commitment to giving research within architecture a recognizable place within society was

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<sup>159</sup>

Ibid., 10.

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Bernal, J [1946a, March]. "The Organization of Building Science Research," *The Architect's Journal*, 224-

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Bernal, J. [1946b, December]. "Is town Planning a Science?" *The Builder*, 657.

<sup>162</sup>

Bernal, J. [1946, March]. "Science in Architecture," *RIBA Journal*, 155-9.

tireless, and in the early forties, considering that architects were an important part of the building industry, and recognizing the need for their involvement in the reconstruction of the country, RIBA set up a 'Reconstruction Committee' with groups of specialists to consider all aspects of the activities of planning, construction and housing. This allowed again Bernal's involvement in the making of new policies.<sup>163</sup>

#### 5.4 Leslie Martin. Research into Practice

Leslie Martin had always been very attentive to what was going on around him, and was very skilled at turning to practical use the issues that were being discussed. The publications of *Circle* in 1937, the establishment of LUBFS in 1967, and the creation of his masterpiece, the London Royal Opera House, in 1951, are brilliant examples of his unique ability to give form to ideas, and to establish successful working teams. By comparing the writings of Bernal and Martin, their contents and years of publication, we see that Bernal had not only started to publish much earlier but had also published far more. It is worth mentioning that Martin's first article dedicated to the relationship between research and building appeared in the same special issue of the *Architect's Journal*, in 1946.<sup>164</sup>

During the mid-30s, while Bernal was active in several political, scientific and social organizations, Leslie Martin had accepted a position as the Head of the School of Architecture at Hull [1934-39] and was also concluding his PhD<sup>165</sup> at the University of Manchester. At Hull Martin, while trying to give a more solid curriculum to the architecture department, continued to be in contact with the British Avant-garde. After Hull, Leslie Martin and Sadie Speight moved to London and for a period of nine years [1939-48] Martin became principal assistant architect with the London Midland Scottish Railway [LMS] developing research into new methods of light construction. After this work, Martin became architect and later chief architect of the London County Council [LCC], where he stayed until 1956, the year that he would become Head of the School of Architecture at Cambridge.

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<sup>163</sup> In 1941 the Institute submitted a memorandum to the Minister of Works and Buildings, in which it was pointed out that: "The training and practical experience of the qualified architect bring him into contact not only with the design of buildings, but with major and ancillary problems connected with it. [...] For the practice of architecture today is not confined solely to plan and elevation, still less to transforming works of practical building into ordered architectural coherence. The qualified architect is a man conversant with those same factual problems of broad aspect which confront a Minister of Works and Buildings, a Minister of Planning, a Minister of Reconstruction," *Rebuilding Britain*. Catalogue of the Exhibition at the National Gallery, London [1943].

<sup>164</sup> Martin, L. [1946, November]. "Research and Practice," *The Architects' Journal*, 396.

<sup>165</sup> Leslie M. [1936]. "The Position of Jose de Churriguera in the Development of Spanish Baroque Architecture." Ph.D thesis. University of Manchester ,UK.

At that time, architecture had no organized research program within the school in Cambridge, and this was barely accepted by the other departments of the University. One of Leslie Martin's main goals was precisely to establish a coherent body of research within the department, and the formative years of the Cambridge School of Architecture were fundamental to his undertaking of this initiative. Under Leslie Martin's leadership, a new generation of architects, such as Christopher Alexander, Colin Rowe, Peter Eisenman, Anthony Vidler and Lionel March, did seminal theoretical work that greatly contributed to the formation of a special architectural environment within the Cambridge school.<sup>166</sup> As head of the School of Architecture, Martin drew on much of the debate that had taken place earlier. The focus on a theory that could inform research within architecture would constitute his main goal for the following decades. Leslie Martin's speech at the 1958 'RIBA Oxford Conference on Architectural Education' was already an official echo on the belief of what architectural education and research should be about. In that occasion Martin pointed out: "The characteristic feature of architectural education is that it involves widely different types of knowledge."<sup>167</sup> These concerns were not new, but rather reminiscent of the discussions that had started in the early teens at the Deutsche Werkbund, in Germany. The significance of these early arguments about the role of design led to a larger discussion on the new kind of training that should be given to architects so that they could master art and technology. For Martin, each developing theory or movement is somehow the reassessment of human needs, whether intellectual, practical, or scientific.<sup>168</sup>

In different European countries there was a common view that technology had an important role to play, and as a consequence, a greater awareness of the changes that architecture would have to undergo, was central to the debate. All these ideas regarding architecture, planning and research, were for the first time put together in an urban context with the 'Whitehall plan'. When Leslie Martin was appointed assistant architect at the LCC in 1948, a plan for the development of South London was being considered, and a particular need for the development of this area was going to arise. Martin's involvement not only led to the realization of the 'Whitehall plan' but also to the construction of what would be Martin's master piece: the London Royal Opera House, on the south bank of the Thames in London.

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<sup>166</sup> For an initial account of the Cambridge School, see: Hawkes, D. [1984]. "The Cambridge School. Tradition, Research, Practice." *Architectural Review*, 33-7.

<sup>167</sup> Martin, L. [1958, June]. "Conference on Architectural Education," *RIBA Journal*, 65, [8], 279-82.

<sup>168</sup> Martin, L. [1978, July]. "Notes on a Developing Architecture," *The Architectural Review*, CLXIV [977], 11-7.

The 'Whitehall plan' was begun in 1965, and was the pretext for Lionel March's return to Cambridge after a stay as a research fellow at the Joint Center for Urban Studies of Harvard and MIT between 1959 and 1965.<sup>169</sup> The necessity of addressing a wide range of design problems related to the built environment favoured the integration of planning with building science, and at the same time fostered concerns regarding the relationship between the use of land and the built form. The research initiated by Leslie Martin and Lionel March at the University of Cambridge, and particularly at LUBFS in the late 60s, showed a fundamental interest in these issues and opened the debate about the usefulness of applying new quantitative methods and theories to planning and architecture. In a broader theoretical context, questioning how to model and create a computational representation of architecture phenomena was also one of the major contributions of LUBFS. We can interpret the 'Whitehall plan' as the embodiment of much of the discussion pioneered by Bernal in the previous decades. In this sense, Martin and March were the mature architects and researchers that were able to combine knowledge and research principles and apply them to a rigors theoretical setting.

### 5.5 LUBFS. Computational premises

The foundation of LUBFS was a response to the theoretical issues that had been pressing since the eve of WWII and the main argument that Leslie Martin wanted to reflect upon was twofold: on the one hand, to discuss the intentions and processes that influence form - form being the end product of a process, not an end in itself - and on the other, a strong belief in the concept of "built form", which encompassed object, subject, and processes. To these two ideas, Martin added a third, rational thought, which would allow for the construction of a new theoretical system. Martin said:

The design of an object becomes a statement of conviction about what a society may need, the way it might consider its surroundings, the kind of products that it might have and how it might manufacture and use them. It is indeed an intellectual commitment.<sup>170</sup>

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<sup>169</sup> The Center was founded in 1959.

<sup>170</sup> Martin, L. [1967, May]. "Architect's Approach to Architecture," *Riba Journal*, 191.

Drawing on the writings about the function of reason by the British philosopher and mathematician Alfred North Whitehead, Martin suggests that only by speculative invention would it be possible to reassess the crisis faced by architecture at the end of the 50s. For Martin it becomes necessary to analyze, to measure, and to rationalize as an, “essential part of the process of scientific thought.”<sup>171</sup> Quoting Edgar Wind, Martin sees that a yawning gap between intuition and rational thought still exists, and this is why architecture does not reinvent its own modern path. Wind states:

But we have preferred, in the main, to continue the old argument and to separate rational assessment from form making. Behind this, without question, lies a nineteenth century fear: the fear that ‘intuition’ might in some way be weakened by Knowledge.<sup>172</sup>

Martin’s view was a reassessment of methods, whereby knowledge would be gathered by the establishment of analysis, enhanced by experiments and confirmed by simulation. It was reassessment that would first be embodied in the ‘Whitehall plan’<sup>173</sup> a period for war reconstruction, where tall buildings were still seen as the best solution for the use of land according to architectural programmatic needs. When Leslie Martin was invited to advise a new plan for the rebuilding of Whitehall, the national government center in London, the solution he proposed with Lionel March involved an architectural scheme developed around the idea of courtyards with surrounding buildings no higher than the existing ones [Fig. 27]. The studies carried out to locate the space within the site were achieved by “number-crunching” on an early card computer, thus representing one of the first uses of electronic computing in architectural design. Researchers at LUBFS developed mathematical models [relying mainly on set theory and graph theory] which were not only designed to represent real urban phenomena, but also to be encoded in computer programs that could describe the physical properties of buildings and the best use of land, in fields such as architecture, environmental design and urban planning. The understanding of how geometrical form could be described symbolically, and also represent a correct relation to its surrounding environment, was one of the principal research goals being pursued at LUBFS. Lionel March says:

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<sup>171</sup> Ibid., 193.

<sup>172</sup> Wind, E. [1963]. *Art and Anarchy*. New York: Knopf, 52.

<sup>173</sup> Martin, L. [1965]. “Whitehall: a plan for the national and government centre,” Accompanied by a Report on traffic by Colin Buchanan. London: H.M. Stationery Office.

The introduction of computer technology into architectural design made the conjunction between Boole's mathematical structure and architectural structure broadly understood, inevitable but not necessarily explicit. It is the purpose of this essay to point towards some concepts which can be shared between Boolean algebra and architectural form, in the hope that this encounter will prove fruitful in the long run even if this may not be wholly obvious now.<sup>174</sup>

The motivation to explore Boolean operations in relation to art, was provided by Lionel March's 1966 exhibition at the Institute of Contemporary Art [ICA], in London. Entitled 'Experiments in serial Art', March exhibited pieces that expressed Boolean operations applied to a set of horizontal and vertical stripes, from which a series of complex designs were made<sup>175</sup> [Fig. 28]. At this time March was starting to be interested in the creative aspects of combinatorics and in, associating thought with music, March wrote:

At this time I was fascinated by the mechanisms of serial music: the inversions and reflections of the tone row, and certain rhythmic and dynamic structures then being introduced by Boulez and Stockausen. Leon Lovett, the conductor, then a fellow student of mine, once sketched out for me a matrix filled with numbers on a napkin in some coffee bar. He explained that this was the way composers were working in Darmstadt, which he had just visited. If music could be encoded in numbers, why not architecture?<sup>176 177</sup>

This was the beginning of a series of studies based on the theme of Boolean point-set operations for design later amplified in March's "A Boolean Description of a Class of Built Forms" [Fig. 29]. Here spatial form is defined by binary relationships, binary diagrams of form, a method of describing rectangular shapes which was applied in architectural design, mainly in the layout planning of large office buildings. The design and implementation of computer programs that were able to manipulate the graph-representations varied between those where just some plans were design, [adjacent requirements satisfied], or instead, where an

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<sup>174</sup> March, L. [1976]. "A Boolean Description of a Class of Built Forms," *The Architecture of Form*. Cambridge: Cambridge University Press, 42-73.

<sup>175</sup> March, L. [1966, February]. "Serial Art," *Architectural Design*, 62-3.

<sup>176</sup> March, L. [1972, March]. "Modern movement to Vitruvius: themes of education and research." *RIBA Journal* 3, 102.

<sup>177</sup> It is also interesting to note the important enterprise that took place in music in the late 60s, fundamentally in the work of Stockausen, and in the International Summer courses for the new music in Darmstadt, Germany, which were initiated in 1946 by Wolfgang Steinecke. An International Center for contemporary music was established in 1963. Distinguished lecturers were: Adorno, Varese, Boulez, Cage,

exhaustive enumeration of all possible design solutions was performed. The problem of the dissection of a rectangular plan by the creation of algorithms that could produce exhaustively all topological solutions was at that time being explored, and represented a particular case of heuristics and combinatorics applied to architecture. Philip Steadman in his "The Automatic Generation of Minimum-Standard House Plans,"<sup>178</sup> illustrates the application of the theory of graphs in the representation and solution of small-scale architectural planning problems. A discussion about the use of graph theory and architecture followed by March and Steadman [1971]<sup>179</sup> and by Steadman [1976] [Fig. 30]. Later, William Mitchell, [Mitchell et al, 1976], took this approach further with the use of dynamic programming, and Cecil Bloch, a research scientist at LUBFS pursued this investigation by designing algorithms for the extensive enumeration of rectangular dissections.<sup>180</sup>

However, point-set operations, heuristics, and the use of exhaustive enumeration applied to these problems, still constituted a particular view of how design could be conceptualized through the computer. An alternative view of computation, which March so much welcomed and later published as editor of the journal *Environment and Planning B*, was the new paradigm that 'shape grammars' represented for design. As grammars are defined by "shapes" that can acquire different symbolic representations according to the chosen rules, and as they do not rely on fixed primitives, they represented a new approach to research into design and computation. March recalls,

Shortly after the publication of *The Geometry of Environment* I came across a volume in the library of Cambridge University's Computer Laboratory called *Information Processing 71*, where I found a paper "Shape grammars and the generative specification of painting and sculpture" by Stiny and Gips which seemed highly relevant to my own work, but whose formalism proved too unfamiliar at the time.<sup>181</sup>

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Ligetti, Nono, Pousseur, Stockausen. Many parallels [and questions] can be made between the work developed in Electronic music and the work in computation and design.

<sup>178</sup> Steadman, P. [1970]. "The Automatic Generation of Minimum-Standard House Plans." 'Land Use and Built Forms Studies'. Working paper 23.

<sup>179</sup> March, L and Steadman, P [eds]. [1971]. *The Geometry of the Environment. An introduction to spatial organization in design*. Methuen & Co Ltd.

<sup>180</sup> Bloch, C. J. [1980]. "Synthesis of Architectural Form: an ALGOL68C Plan Grammar Processor." Martin Centre Working Paper. See also, Bloch, C.J and Krishnamurti, K. [1978]. "The Counting of Rectangular Dissections." *Environment and Planning B*, [5], 2. Bloch's PhD Thesis at the University of Cambridge: *A Formal Catalogue for Small Rectangular Plans: Generation, Enumeration and Classification*. 1979.

<sup>181</sup> March, L. [1981]. "Theme issue: design and language," *Environment and Planning B*, [8], 241-3.

Soon after, "Two exercises in formal composition"<sup>182</sup> was published and opened the field to new possibilities. Subsequently a work by Stiny and Mitchell, "The Palladian Grammar,"<sup>183</sup> represented a new path in generative design, this time developing a grammar that generated the ground plans of Palladio's villas [Fig. 31]. Architectural features of Palladian architecture could be inferred and codified in a series of rules that would constitute the generative grammar for the design of new forms within a particular formal context. Reviewing the research work of this period, probably one of the richest, Michael Batty commented:

This work has evolved in diverse ways from shape grammars to network models but it is based on the very firm belief that explanation and design are one and the same, and that a deep understanding of form must be based upon processes in which rules executed locally generate structures that display global order.<sup>184</sup>

In the next chapter we highlight part of this work that was carried out at LUBFS and how it fostered the beginning of a new 'Diaspora' of research, this time from the UK to the USA.

## 5.6 LUBFS . Research Groups

LUBFS had five major research groups,<sup>185</sup> and most of the work undertaken was published in three major publications; *The Geometry of the Environment*, [1971], *Urban Spaces and Structures*, [1972], and *The Architecture of Form*, [1976]. These publications, besides making available to a wider audience the research that was being conducted at the Center, aimed to illustrate the importance of the use of mathematics in the development of a theory that could meaningfully engage architecture. In the foreword to *The Geometry of the Environment*, Leslie Martin wrote:

The point is that if mathematics is thought of as a 'logical pattern of entities and relationships' then these may perhaps be seen to be reflected in the physical and spatial arrangement of buildings. [...] To recognize and to admit this relationship is to deepen and stimulate a whole area of thought

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<sup>182</sup> Stiny, G. [1976]. "Two exercises in formal composition," *Environment and Planning B*, [3], 187-210.

<sup>183</sup> Stiny, G and Mitchell, W. [1978]. "The Palladian Grammar," *Environment and Planning B*, [5], 5-18.

<sup>184</sup> Batty, M. [1994]. "Urban models 25 years on," *Environment and Planning B*, [21], 515-6.

<sup>185</sup> Urban Studies with Marcial Echenique; University Planning with Nicholas Bullock, Peter Dickens and Philip Steadman; Office Design and Environmental Assessment with Dean Hawkes, Philip Steadman and Richard Stibbs; and Built Form Studies, with Lionel March and Philip Steadman.

about architecture. We become aware of another way of looking at a design problem through which we can consider more effectively and rigorously the ranges of choice that are open to us.<sup>186</sup>

This represented one of the theoretical cornerstones of the Center, and also of Leslie Martin and Lionel March's thinking. In the same publication March states clearly:

With true theory, not the manifestos of the second machine age, our knowledge can be more certain, our predictions more reasonable, our assumptions more explicit, and our understanding more aware of its shortcomings. In our view, developments of scientific attitudes and growth of fundamental theory are essential prerequisites before any socially significant improvements can be made in architectural or planning practice.<sup>187</sup>

The outcome of these theoretical ideas and the development of computer models occurred at a time when computational technology was still in its infancy. One of the first applications of these theoretical and technological premises took place with the work carried out by Dean Hawkes and Richard Stibbs.<sup>188</sup> Hawkes, who came to Cambridge in 1964 as a research assistant, and Stibbs, a computer scientist and research associate with the computer unit of the Center, developed a computer program that explored the relation between the building envelopes and energy performance, a model focusing on the evaluation of the environmental performance of individual rooms or of whole buildings. To this end they designed a computer program to do computations that involved thermal, visual and acoustic performances. Dean Hawkes recalls:

The core of the work was a computer model that calculated aspects of the thermal, visual and acoustic properties of building environments, which were tied together with a building description where 3.500 lines of code were written in FORTRAN 4 [...] The University had this big machine called TITAN, reconfigured with components built by *Teranti*, an Italian electric engineering company which in the 60s began to produce some mainframes. This machine became the prototype of the British computer company ICL, and at the time was seen as a rival to IBM.<sup>189</sup>

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<sup>186</sup> March, L. and Steadman, P. [eds]. [1971]. *The Geometry of environment. An introduction to spatial organization*. London: Methuen & Co Ltd, 6.

<sup>187</sup> *Ibid.*, 275.

<sup>188</sup> R. J. Stibbs, Dissertation Submitted for the Diploma in Computer Science, Cambridge University Mathematical Laboratory. 1968. 'A Computer Aided Design Analysis System. See also, Stibbs, R and Steadman, P. [1968]. "A Computer Aided System for Architectural Design and Analysis." *Cambridge Research*, [2], 1, 18-22.

<sup>189</sup> D. Hawkes [Interview with the author, April 23<sup>rd</sup>, 2002, Cambridge, UK].

These were the protodays of computing; LUBFS had one terminal connected to a time-sharing system, out of a total of 12 terminals in the whole university for remote accessing of the principal mainframe with teletypes. In the meantime, recent graduates started to work on innovative research projects that were established under Leslie Martin's guidance. One of the first projects to get under way was the construction of the geodesic dome, enclosing an artificial sky for the prediction of daylight levels in buildings. David Croghan, a graduate student of the school, conducted this work, which constituted his PhD thesis<sup>190</sup> and Dean Hawkes, who came to Cambridge as a research assistant in 1964, mentioned the excitement of this early research project:

The design and construction of the Sky Dome was a remarkable idea and Leslie Martin was enthusiastic about it. This was proto to the foundation of LUBFS, and these were early concerns with the built form, with day lighting, the spacing of buildings in order to achieve certain standards of daylight, and the Sky Dome was very much seen as part of that enterprise. It was used to study the use of daylight in buildings by researching spatial configurations regarding window size and was also used to test some projects at Leslie Martin's office.<sup>191</sup>

Two years after the foundation of LUBFS, and due to the increased volume of produced research<sup>192</sup>, a spin-off company was formed. Applied Research Cambridge Ltd [ARC], created in 1969, pioneered the development of software such as 'GDS', a computer aided design program for use in architecture, engineering and urban planning.<sup>193 194</sup>

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<sup>190</sup> See project description: Croghan, D. [1964, July]. *Architects Journal*.

<sup>191</sup> D. Hawkes, [Interview with the author, April 23<sup>rd</sup>, 2002, Cambridge, UK].

<sup>192</sup> Between 1967 and January 1974, researchers at LUBFS produced 77 working papers, and from 1974 onwards, technical reports were collected into volumes entitled *Transactions of the Martin Center*.

<sup>193</sup> Developed by Paul Richens a graduate student at the Center. Today Richens is the Director of the 'Martin Center.'

<sup>194</sup> In 1984, the USA Company McDonnell Douglas Corporation acquired ARC. Another entrepreneurship was set up in 1978 with Marcial Echenique & Partners Ltd who developed the MEPLAN software, which started to be used as computer-aided land-use and transport planning in several projects outside the UK. In 1986, Cambridge Architectural Research Ltd was established to support the transfer of research and ideas developed at

## 5.7 The Open University. The Second Diaspora

“The interest was modelling and simulation, and any interest in generative approaches went to the United States.”<sup>195</sup> ‘Diaspora’ was at that time an apt description of the journey that led the search for a place where ideas could find their materialization, where concepts could grow and benefit mutually. The research knowledge and academic experience gained since the mid-60s, particularly at LUBFS, merged at The Center for Configurational Studies [CCS] of the Open University at Milton Keynes, UK. The Center was founded in 1978, within the Design Discipline, by Lionel March, who had a strong reputation and interest in combinatorial mathematics and who had the idea to create a center where research could be developed to explore the potential use of combinatorics in different fields. Steadman who also moved to this new Center explains:

Lionel had a vision that there would be things in common between the enumeration of mechanisms in mechanical engineering [he was very keen on the work of Franz Reuleaux<sup>196</sup>, who developed a kind of algebra of mechanisms], and the beginnings of a systematic and mathematical approach to the description and enumeration of mechanical possibilities. You have basic elements, building blocks, and various ways of assembling them together. These structures can behave in different ways and be applied to different fields.<sup>197</sup>

Lionel’s interest in shape grammars, in rule based generation of form, took on a new emphasis during his stay at the Department of Systems Design and Engineering, in Waterloo, Canada, where he launched new research projects and where he met Ramesh Krishnamurti, who would later become his PhD student at the Open University, and who was responsible for the computer implementation of Shape Grammars. As Professor of Design at the CCS, from 1978 until 1981, March conducted research into morphology and computable design and this is when he invited George Stiny to join the center. These settings allowed new work to be carried out, but The Open University project would reach to a watershed, and some of its principal would leave. Steadman recalls:

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the Center to real practical application, mainly in the fields of environmental design and acoustics, as well advising on third-world housing design and studies in CAD.

<sup>195</sup> Philip Steadman. [Interview with the author, April 23<sup>rd</sup>, 2002, London, UK].

<sup>196</sup> Reuleaux, F. [1963]. *The Kinematics of Machinery; outlines of a Theory of Machines*. New York: Dover Publications. [1st edition 1875].

<sup>197</sup> Philip Steadman. [Interview with the author, April 23<sup>rd</sup>, 2002, London, UK].

What really happened was that even if these works were extraordinary for a research center with enough interdisciplinary paths, one individual mainly represented the disciplines. What simply held together was the idea of art and of mathematical modelling, particularly combinatorics, but that was probably not enough, and the center as it was could not last much longer. It was an engineering faculty and we were regarded as complete foreigners.<sup>198</sup>

Later March became Provost of the Royal College of Art until 1984 and Bill Mitchell, who was at the Martin Center, became in 1977 the Chair of the Architecture and Urban Design program at UCLA, USA. Two years later George Stiny joined UCLA's Graduate School of Architecture and Planning to teach, with Mitchell, the first research program in shape grammars. This was the beginning of a new Diaspora to the US, where many of the ideas about computation and architecture started to be incorporated into design studios for the first time. Lionel March came in 1984 to UCLA and three years later, Mitchell's departure to Harvard University brought Charles Eastman from Carnegie Mellon to UCLA, to develop the department's strengths in CAD systems. In 1995 Eastman went to the Georgia Institute of Technology, and Stiny now joined Mitchell as Dean at MIT.

Otherwise these routes could start to be mapped when in 1966 George Stiny and James Gips, still students of Marvin Minsky at MIT, did pioneering research into the digital recognition of "hand tool shapes", or when Bill Mitchell, before leaving for the UK, was a graduate student in Serge Chermayeff's last class at Yale University in 1968.<sup>199</sup> The establishment of these research agendas both at LUBFS, and at CCS, and the increasing number of graduate students doing PhD research in this area, were fundamental to the putting into practice of the efforts that were passionately invested in the early 60s at the Scroop Terrace, Cambridge. The renewed interest that some contemporary architectural offices have started to show in research emerging from University Architectural Labs can be seen as an optimistic endeavour.<sup>200</sup> Part of these new possibilities are briefly illustrated in the Appendix of this thesis.

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<sup>198</sup> Philip Steadman. [Interview with the author, April 23<sup>rd</sup>, 2002, London, UK].

<sup>199</sup> Mitchell, W. [1969]. *Synopsis of Conclusions and Record of Process. The Chermayeff Studio*. Autumn, 1968-69. [New Haven: Yale University School of Arts and Architecture, January].

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Denis Shelden [PhD, MIT, Dept. Architecture] is director of computing at 'Gehry and Partners' and developed a plugin for 'Rhino' and 'Catia' that allows the modelling of surface strips that constraint the geometries to developable ones. Axel Kilian [Doctoral Candidate at MIT, Dept. Architecture], is conducting research in parametric features for 'Microstation', Bentley Systems. These are two examples among others.

## CHAPTER 6 The American Counterpoint

## 6.1 Computational background

From the early 60s to the late 70s the construction of digital technologies, the experimental appliance of modelling to architectural and urban phenomena and the development of problem solving techniques characterized much of the endeavours carried out in this field. An overview of the computational foundations of architectural design during these decades was carried out by Mitchell [Mitchell, 1977]. This work illustrates an approach where architectural design is generally seen as a special kind of problem-solving process, where spatial representations of the stated problem are formulated and where problem solving is characterized as a process of searching through a space of generated solutions.

An exception to this view of design was given in George Stiny's and James Gips's [1972] proposal of a 'shape grammar'. For Stiny design is reasoning, a speculating possibility that suggests that before "reasoning", design is also "visual reasoning"; therefore "seeing" is a property that characterizes the process and creativity in design as a practice which is not defined only by the decomposition of its elements into fixed units. This view proposes a possible different computational model, one that is not dependent exclusively on the combinatorial possibilities of the computer, but rather on exploring the visual manipulation and interpretation of 'form'. Stiny's argument for shape grammars leads to questions underlying the proper logic of computational systems, as well to questions of architectural languages and their computational representation [Stiny, 1986]. Mitchell [1990] gives a broader context in which these two postures coexist.

During this period, theory on the one hand, was being challenged by the validity of the inherited critical methods of the Frankfurt school and on the other, by the views and processes that computation was gradually widening up and by the end of the 80s and early 90s the question to be asked in this domain was clear: how to combine theoretical investigation with the use of already existent computational tools? One of the first responses relied in the transfer of traditional processes into computational domains where precedents kept their epistemological truth [top-down approach]. Other attempts tried to take the inner logic of the computer as the source to create new concepts, which were not necessarily dependent on architectural precedents [bottom-up].

This necessity of conceptualising brought to light concepts such as: “monad”, “fold”, “unfold”, “morphing”, “warp”, “hybridisation”, “adaptation” and “complexity” all theoretical concepts that emerged within a new computational context<sup>201</sup> [even if sometimes not clearly expressed or too much dependent on the used software] and had to be applied, either as concepts in the design of the software, or as computational and theoretical metaphors that enabled the use of the software. Computational theory [finite state machines, heuristics, optimization, grammars, shape grammars, cellular automata] had now to be critically engaged and the design and construction of software thus became part of the process of design. The architect becomes as much the architect of the ‘place’ as of the computational system, now the new ‘genius loci’s’. This new theoretical transfer through the use of concepts such as “fold” or “monad” represented this time a shift from a branch of post Marxian philosophy which was embodied in some to the ideas of the French philosopher Gilles Deleuze. Indeed Deleuze’s *The Fold, Leibniz and the Baroque* [1993] contextualizes Baroque not in the light of an aesthetic history, nor of religious values, but rather associating it to the ideas of the German philosopher Gottfried Leibniz. The “fold” the “pleat” the “machine” appeared thus as constituents of an initial set of terms created by Deleuze that enabled the construction of his philosophy of social critique and which would be theorized and embodied in computational experiments carried out by architects.

The ‘creation’ of concepts, their theorization and interrelation with computational theories [and software] constituted a new method that necessarily contrasts with previous historical paradigms of architecture production. The appreciation of these new processes constitute the corollary of a debate that started in the early 60s by the same architects who were responsible to bring into light, modernism in the UK.

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See: Novak, M. [1988, October]. “Computational Compositions,” *Computing in Design Education*, ACADIA’88 Workshop Proceedings, ed. P.J. Bancroft, Ann Arbor, University of Michigan, 5-30, and Eisenman, P. [1992]. “Visions Unfolding: Architecture in The Age of electronic Media,” *Domus*, [734], 17-24. Also: Lynn, G. [1993, March/April]. “The folded, the Pliant and the Supple,” *Architectural Design*, 102.

## 6.2 Alexander and Chermayeff . The beginning of the debate on the role of computers in design.

Chermayeff, after staying in the UK between 1924 and 1940, decided to leave and settle in San Francisco, USA. Following a series of different positions, he was appointed professor at the Graduate School of Design [GSD] at Harvard, where he began the formulation of an interdisciplinary curriculum in 'Environmental Design'. Later, his speech at the first 'Urban Design Conference' held at Harvard in 1958, reveals his concerns regarding the need to study the structuring principles of cities, the underlying patterns of physical form in respect to communication and other functions of urban infrastructure. The search to describe the variety of elements and events that constituted the organism "house", with corresponding studies of low-rise housing types, was initiated by Chermayeff at his seminars at Harvard. In 1959, Christopher Alexander joined the GSD to pursue his studies and became research assistant on 'The Urban Family House Project', which expanded Chermayeff's initial premises. Sponsored by the Joint Center for Urban Studies of Harvard and MIT, their project avowed that every design problem has a structural pattern of its own, and that a successful design depends on the designer's ability to understand this hidden structure and on his creativity in manipulating it. The results of this work were published in *Community and Privacy*<sup>202</sup> 1963, where an early 'scientific' method for the drawing up of a taxonomy of elements was presented: 'basic requirements' that could describe the syntactic 'meaning' of what a "house" is and the relationship between "house" cells and city structures.

The *Community and Privacy* experiment was seminal to the testing of computers for the formulation of an architectural experiment, and used the IBM 704 from the Computation Center at MIT, a partnership that Chermayeff very much welcomed as it encouraged the exploration of new design possibilities. The IBM 704 also constituted a technological support for Alexander's further research at Harvard: his Ph.D thesis *Notes on the Synthesis of Form*<sup>203</sup> represented as well one of the early attempts to apply mathematics to the modelling of architectural and urban problems, and thus continuing the research initiated previously with Chermayeff, now his Ph.D advisor.

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<sup>202</sup> Chermayeff, S & Alexander, C. [1963]. *Community and Privacy. Toward a New Architecture of Humanism*. Garden City, N.Y., Doubleday.

<sup>203</sup> Alexander, C. [1964]. *Notes on the Synthesis of Form*. Cambridge: Harvard University Press.

The mid-60s saw advances in the field of digital technology; Ivan Sutherland's *Sketchpad*, the very first interactive CAD system, was completed at MIT<sup>204</sup>; commercial companies were developing the first CAD packages; and discussion about the use of new technologies in urban planning, transportation and in economic matters was also taking place at The Joint Center for Urban Studies of Harvard and MIT. These and other premises about bringing computers and mathematics into architecture and design were presented by then at the conference 'Architecture and the Computer'<sup>205</sup>. This gathering was one of the first public forums to bring together architects, computer scientists, planners and economists inquiring into the possibilities of the use of computers in their fields. Architects, who had so enthusiastically contributed to the construction of the modernist spirit in the UK in the 30s, were now, 30 years later in the USA, discussing the role of computers within architecture. Walter Gropius, Serge Chermayeff, Christopher Alexander and the computer scientist Marvin Minsky, from MIT, were among a distinguished panel of speakers. Focusing on the need for an architectural awareness of the use of computers, Gropius said in his talk:

We seem to be always wrong when we close the door too early to suggested new potentialities, being often misled by our natural inertia and aversion to the necessity of transforming our thoughts. Being not at home in the vast new field of computer systems, I want to be cautious. Still I believe, if we look at those machines as potential tools to shorten our working processes, they might help us to free our creative power [...] What I cannot envisage yet is a practicable method for the average architect or designer to use these tools at the moment when they are needed. The emphasis will certainly be on the intelligent formulation of the questions to be answered by the computer. Will it then be necessary to educate a new profession of architectural assistants for the purpose of articulating the problems to be solved in the proper language of the computer?<sup>206</sup> [Fig. 32].

In conclusion Gropius remarked:

Meanwhile I wish we architects would keep an open mind towards the new possibilities offered us by science. The increasing comprehensiveness of our new tasks in architecture and in urban developments needs new elaborate tools for their realization. It will certainly be up to us, architects

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<sup>204</sup> Sutherland, I. [1963]. *Sketchpad*. Ph.D thesis at MIT.

<sup>205</sup> Held in December 1964, at the Boston Architectural Center.

<sup>206</sup> Serge Chermayeff Archive, Avery Archive, Columbia University. NY, NY. Gropius, W. [1964, 4<sup>th</sup> December]. "Computers for Architectural Design." Paper presented at the 'Architecture and the Computer' Conference, Boston Architectural Center. Boston.

to make use of them intelligently as means of superior mechanical control which might provide us with ever-greater freedom for the creative process of design.<sup>207</sup>

The discussion continued with Alexander's view of the use of computers. In his talk entitled "A Much Asked Question about Computers and Design," he said:

In asking how the computer might be applied to architectural design, we must, therefore, ask ourselves what problems we know of in design that could be solved by such an army of clerks [...] In the present state of architectural and environmental design, almost no problem has yet been made to exhibit complexity in such a well defined way that it actually requires the use of a computer<sup>208</sup> [Fig. 33].

Further, Alexander mentions a crucial problem:

But there is a danger in the currently fashionable preoccupation with computing machinery, which goes far beyond irrelevancy. The effort to state a problem in such a way that a computer can be used to solve it will distort the view of the problem. It will allow us to consider only those aspects of the problem, which can be encoded – and in many cases these are the most trivial and the least relevant aspects.<sup>209</sup>

These views clearly highlight the potential and shortcomings of the use of computation within architecture. As mentioned before, design criteria and architecture problem definition constitute a twofold area where theory should act as a computational mediator.

Part of the work carried out at the Continental Cambridge was now being discussed in the USA and embodied a pioneer transatlantic journey that was seminal to the implementation of new design paradigms in the USA. In this regard Dean Hawkes observed: "In the mid-50s, in both the United States and Britain, there was widespread debate about the aims and methods of architectural education. Chermayeff and Martin both played leading roles in

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<sup>207</sup> Serge Chermayeff Archive, Avery Archive, Columbia University, NY, NY. Gropius, W. [1964, 4<sup>th</sup> December]. "Computers for Architectural Design." Paper presented at the 'Architecture and the Computer', Conference, Boston Architectural Center, Boston.

<sup>208</sup> Serge Chermayeff Archive, Avery Archive, Columbia University, NY, NY. -Alexander, C. [1964, 4<sup>th</sup> December]. "A Much Asked Question About computers and Design." Paper presented at the 'Architecture and the Computer' Conference. Boston Architectural Center, Boston.

<sup>209</sup> Ibid.

this.”<sup>210</sup> Chermayeff’s and Alexander’s experiments at Harvard, constituted the initial offspring of this research path which subsequently lead to the appearance of the field of environmental design, to which both Alexander and Chermayeff started to devote their academic careers<sup>211</sup>.

### 6.3 Herbert Simon and Allen Newell

While in the late 50s and mid 60s, research premises were being nurtured at both Cambridge’s, in Santa Monica, California<sup>212</sup>, a different path in the field of computer science was taking place. Driven by a scientific context and with a strong intellectual affinity with positivist thought, problem-solving research was carried out by the economist and computer scientist Herbert Simon and by Allen Newell also a computer scientist.

It is important to briefly highlight the philosophical tradition of Positivism in the USA, as it was seminal to Simon’s investigation. Positivism was embodied in the work of the Austrian philosopher Rudolf Carnap [1891-1970]. Carnap, who was part of the ‘Vienna Circle’, moved to Prague in 1931, where he became professor of natural philosophy at the German University. Later, in 1935, helped by the American pragmatist philosophers Charles Morris [1901-1979], and Willard Quine, [1908-2000], he moved to the USA to become a professor at the University of Chicago [1936-1952]. Already in the USA, he wrote *The Logical Syntax of Language*<sup>213</sup>, which constituted one of the finest contributions to the field of logic. Simon arrived at the University of Chicago in 1939, and three years later began his graduate studies on the application of mathematics to empirical matters. At the University of Chicago Simon also met two other Faculty members, who would have an important effect on the development of his ideas: the mathematical biophysicist Nicholas Rashevsky and the mathematician Henry Schultz, whose book *The Theory and Measurement of Demand*<sup>214</sup> provided Simon with a deeper view about the use of mathematics in economics. Simon who regularly attended R. Carnap’s courses on logic and philosophy of science, commented: ”All three men communicated to me in their lectures something of how science – at least science involving the applications of mathematics – was done.”<sup>215</sup> With these influences, Simon

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<sup>210</sup> Hawkes, D. [2001]. “The Shaping of Architectural Research,” *arg*, 5 [3]. Cambridge: Cambridge University Press, 205-09.

<sup>211</sup> Respectively at University of California at Berkeley and Yale University.

<sup>212</sup> At the RAND Corporation.

<sup>213</sup> Carnap, R. [1937]. *The Logical Syntax of Language*. London: Routledge & K. Paul Ltd.

<sup>214</sup> Schults, H. [1938]. *The Theory and Measurement of Demand*. Chicago: The University of Chicago Press.

<sup>215</sup> Simon, H. [1996]. *Models of my Life*. Cambridge, Massachusetts, London: MIT Press, 53-4.

geared his research to decision-making in organizations, and in a letter written to Carnap during the summer of 1937, he says:

Dear Prof. Carnap: You will remember me as one of the auditors of your course last winter in 'Logical Foundations of Mathematics.' I was very much interested in the possibilities of applying your methods, and those of Prof. Morris, to an analysis of the social sciences, and I am now writing a thesis in the Department of political science on 'The Logical Structure of an Administrative Science.'<sup>216</sup>

Simon's research into the descriptive study of organizational decision-making continued, and this interest guided his work towards the development of a theory of human problem-solving that would enhance our understanding of human thinking. Herbert Simon, Allen Newell and Cliff Shaw would later successfully pursue this research goal at the RAND Corporation. RAND [an acronym for Research and National Development], was established in 1948 as a way to continue the scientific program initiated during WW II for the USA Defense Department.<sup>217</sup>

Allan Newell had a major in physics from Stanford University. While at Stanford, Newell met the distinguished mathematician George Polya and was introduced to the "art" of heuristics through Polya's book *How to Solve it*, published in 1945. According to Simon, it was their mutual interest for heuristics that brought them together when they first met in 1952 at RAND. Taking a leave from Princeton University, Newell went to RAND to work in a group that was studying the logistics problems of the Air Force; his papers showed an interest in game theory, which had shortly before been invented by John von Neumann.<sup>218</sup> Working with RAND systems programmer Cliff Shaw, Newell's task was to find a way to simulate a radar display of air traffic, at a time when no technology was yet available. Cliff and Newell conceived a Card-Programmed Calculator, predecessor of the first stored program computer, which could calculate the succession of air pictures, printing it as simulated radar maps. This

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<sup>216</sup> Ibid.

<sup>217</sup> An interesting feature of RAND was its opening of a wide range of disciplinary fields and the existence of residency programs for academics of others disciplines. This interdisciplinary interchange of researchers enhanced the discussion among new disciplines, particularly of A.I. The philosopher Hubert Dreyfus, who had taught at MIT in the early sixties, [when the field of A.I was entering its second phase, with the work of Marvin Minsky and Simon Papert] moved to RAND in 1965. There he met Shaw, Newell and Simon, and from this day on, Dreyfus launched his critique of the methods that Simon and Newell were developing. In an earlier RAND memo, Dreyfus published one of his seminal papers on the subject, *Alchemy and Artificial Intelligence*, a paper which was published shortly before Newell and Simon's work in symbolic representations.

was the beginning of their interest in information processing, a subject in which Simon was very much involved. Later, the joint work of Simon and Newell at Carnegie Mellon University pioneered research focusing on heuristically guided search, which, according to Simon, was the best way to confirm the assumption that human intelligent behaviour is also a form of “information processing.”

This was the time when the first programs to successfully solve significant non-numerical problems had appeared. Research on chess was being aimed towards the understanding of human chess players, and chess programs were designed by Newel, Simon and Baylor<sup>219</sup>; in 1957 they published a description of the Logic Theorist [LT]<sup>220</sup>, a program that proved all the theorems in Whitehead and Russell's *Principia Mathematica*<sup>221</sup> and the General Problem Solver [GPS] had been conceived. At this time W. Ross Ashby published *Design for a Brain* [1952], Alan Turing's influential paper “Can a Machine Think” was published in the Journal *Mind* in 1950; Norbert Wiener had created the field of ‘Cybernetics’ [1948]; Claude Shannon not long before did revolutionary research on switching circuits [1938] which theoretical principles were now being applied; and the work of Walter Pitts and Warren McCullough [1943] on the application of Boolean logic to nerve networks had been published.

This particular context influenced Simon and Newell to venture in the discover of features of human thinking mechanisms, -“primitive information processes”- which could be coded and executable on computers. Their Information Processing Theory [IPT] thus appeared to be the right tool for combining principles of psychology with principles of computation. The making of this new theoretical framework would also be seminal to innovative work in the area of “design methods”, which would be led by the architect Chuck Eastman at Carnegie Mellon University [CMU].

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<sup>218</sup> In 1954, John von Neumann, was building the computer ‘Johnniac’ at RAND.

<sup>219</sup> NSS [Simon and Newell, 1958], and MATER [Baylor and Simon, 1966].

<sup>220</sup> See, Newell, A and Simon, H. [1956]. “The Logic theorist Machine,” *IRE Transactions on Information Theory* IT-2. 3.61-79.

#### 6.4 From RAND to The Design Research Center

All these scientific, technological and philosophical issues, which fused at RAND, would constitute a particular kinship with the studies that would soon be implemented at The Design Research Center [DRC], founded at CMU in 1975<sup>222</sup>. The intellectual tradition of the center can be found around 1968, when Simon was invited to give the 'Karl Compton Lectures' at M.I.T. Simon's series of lectures was entitled 'The Sciences of the Artificial', and its main topic was the "science of design", a theme that showed Simon's belief that new computer programs in artificial intelligence were changing the intuitive and mysterious processes that designers usually applied. Now it would be possible to understand with accuracy what really constituted the process of design. Simon stated: "design theory is aimed at broadening the capabilities of computers to aid design, drawing upon the tools of artificial intelligence and operations research."<sup>223</sup>

The DRC would thus carry out work within this 'ideology', trying to improve teaching and engineering in design. According to Simon, when studying the process of design, we discover that design is a problem-solving activity, and that a basic theory of problem solving opens the door to a specific theory of design, one driven by the rules of a quest for optimisation - understanding design was also a way to understand human mental information processes -. With this method/theory the development of algorithms makes it possible to find optimal or satisfactory design solutions, using either linear or dynamic programming techniques. This represented a very specific context in which the "science of design" could be explored and implemented.

In the mid-70s, Carnegie Mellon University, recruited from the engineering departments a few faculty members who shared this view. Gary Powers and Steve Director were among the first. Soon after, Charles Eastman, who had been Christopher Alexander's student of architecture at the University at California at Berkeley, and later of Herbert Simon's at Carnegie Mellon, was appointed to the Faculty of the Departments of Architecture and Computer Science. This new Faculty initiated a series of research projects that became crucial to the field of computer-aided design within architecture. The first Ph.D program was launched in 1969, Eastman became Professor of architecture and Computer Science [1974-1982] and his first graduate student, Chris Yessios, concluded his Ph.D thesis in 1973.

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<sup>221</sup> See the correspondence between Herbert Simon and Bertrand Russell regarding the Logic Theorist. *Ibid.*,207-211.

<sup>222</sup> Since 1985 called the 'Engineering Design Research Center'.

Entitled *Syntactic Structures and Procedures for Computable Site Planning*, Yessios work expressed the use of language for automated space planning, working on a linguistic approach to problem solving [shape grammars and generative grammars]. A direct offshoot of this research was the design of the software *FormZ*.<sup>224</sup>

## 6.5 From Vennevar Bush to the Architecture Machine Group

Simultaneously, this new view that mental phenomena are guided by interrelations between mental states, where the function of the mind is compared to that of a computer program, opened up a wide range of possibilities to architecture research. A center that embodied part of this view of computation was the Architecture Machine Group [AMG], founded by Nicholas Negroponte at MIT in 1967. Negroponte, driven by MIT's technological context, conducted research into the notions of 'information' and of 'evolutionary machines', notions which were greatly expanded during the war period. However, within a broader conceptual sphere, Negroponte's ideas were greatly influenced by the early writings and innovative technological vision of Vennevar Bush.

Vennevar Bush was an electrical engineer from Tufts College and MIT, who in 1919, after having worked at General Electric and taught at Tufts University, joined the staff of MIT's Department of Electrical Engineering.<sup>225</sup> This was the decade between the Great War and the American Depression, but it was also a period that constituted a bull market for engineering enrolment in the Electrical Engineering Department at MIT, which almost doubled during this time. Moreover, the interwar years found corporate and philanthropic donors willing to donate to research and development within the university.

Bush's influence on Negroponte's work is very much driven, we suggest, by his acknowledged essay, "As we May Think",<sup>226</sup> published in the summer of 1945. Here, Bush represented the description of a machine, *Memex* that could explore the potential utility and application of new kinds of machines for managing information and representing knowledge. The Editor's note in *Atlantic Monthly*, where this paper was first published, read: "He urges that men of science should then turn to the massive task of making more accessible our bewildering store of knowledge. For years inventions have extended man's physical powers

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<sup>223</sup> Simon. H. [1969a]. *The Sciences of the Artificial*. Cambridge: MIT Press, 114.

<sup>224</sup> Work at the DRC pursued with Ulrich Flemming and Omar Akin.

<sup>225</sup> In 1932 Vennevar Bush became Dean of the School of Engineering and vice president of MIT.

<sup>226</sup> Bush, V. [1945, July]. "As We May Think," *The Atlantic Monthly*. 176, [1], 101-8.

rather than the powers of his mind.”<sup>227</sup> *Memex* was an optimistic technological vision that took advantage of all the available knowledge and efforts achieved during the war period. “As We May Think” drew up a long list of possible innovations in the domain of information processing and in the area of information display. These were related to the main concern, namely that scientists had produced an enormous amount of information but that retrieval of this information was not compatible with the needs of the world and of science. Bush says: “Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose.”<sup>228</sup>

The range of Bush’s ideas matched those outlined later by Negroponte at the Architecture Machine Group. They were in essence isomorphic. In the preface of *The Architecture Machine*, Negroponte wrote:

The design process, considered as evolutionary, can be represented to a machine, also considered evolutionary, and a mutual training, resilience and growth can be developed [...] I shall consider only the third alternative and shall treat the problem as the intimate association of two dissimilar species [man and machine], two dissimilar processes [design and computation], and two intelligent systems [the architect and the architecture machine].<sup>229</sup>

The drawing of this Computational ‘mapping’ has however an earlier starting point: the pioneer work that soviet architect Nikolai Krasil’nikov’s carried out when student of Moisei Ginszburg at the Vkhutemas school of architecture, Moscow. Krasil’nikov’s believed that the introduction of scientific and quantified methods into the process of design was the best path to overpass the shortcomings of the ‘traditional’ methods of design. His work stands as a truly pioneer influence.<sup>230</sup>

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227

Ibid.

228

Ibid., 101-8.

229

Negroponte, N. [1970]. *The Architecture Machine: toward a more human environment*. Cambridge: MIT Press.

230

See, Cooke, C. [1975]. “Nikolai Krasil’nikov’s quantitative approach to architectural design: an early example. *Environment and Planning B*, [2], 3-20.

## CHAPTER 7 Conclusions

## 7.1 01

The nature of the development of architecture theory in the Cambridge School of Architecture was considerably informed by scientific principles, where Logical Positivism constituted one of the most important philosophical trends and influences. It was within this philosophical context that Leslie Martin forged the development of a new theory and research agenda for the school of architecture at Cambridge. Moreover, the pre-war context of the thirties was the springboard for Martin's concerns regarding the necessity of relating architecture to the building sciences. First, due to WWI there was a lack of housing and an urgent need to find innovative [standardized] solutions for the building industry; secondly, the emergence of WWII and the urgent need to minimize the consequences of air attacks, led to research in building science carried out by multidisciplinary teams of architects, engineers and scientists; and thirdly, the involvement of the Department of Scientific and Industrial Research and of the Royal Institute of British Architects in the setting up of various architecture research committees was seminal to the promotion of a new relationship between various scientific fields and architecture. In this context of the inter-war period, Cambridge and London started to witness the gathering of architects, artists, and scientists at Hampstead and at the 'Finella' house in Cambridge. These gatherings attended by many of the Bauhaus refugees and by Russian artists and architects, greatly informed the beginning of the debate on the role of art and science within architecture, the direct outcome of which was the publication of *Circle*.

At the outbreak of WWII, the seed of modernism in the UK had already been sown. The first major modern buildings were constructed; the Hampstead 'gentle nest of artists' was dispersed between London and St.Ives, and abstract and constructive art finally made their debut. Nonetheless, for the building industry, planning and architecture, the consequences of the war would have an enormous impact, particularly through the innovative scientific and civil engineering research that had arisen from the necessity to study existent civil shelters for air-raid defense. The warfare program constituted not only a scenario where architects and scientists had to meet and collaborate, but also constituted a challenge for the development of new theories, methods, and applied research. This network of events that took place during the thirties, not only created a series of significant architectural pieces, of Constructive and abstract art, but more fundamentally, it allowed the formation and consolidation of an interdisciplinary framework which, in the following decade [with the outbreak of the war],

would be incorporated into a more accurate relation between building science and architecture.

This thesis argues that this intellectual environment was crucial to the development of the ideas that would lead to the appearance of LUBFS, but at the same also tries to demonstrate that the principal figure in fostering these ideas was Desmond Bernal. Bernal's diaries, letters and published articles very strongly illustrate his long interest in art, architecture, and building science research. If Martin, along with Lionel March, was the mentor responsible for putting research into practice, it was Bernal who first brought architecture into the field of research, and of relating science and architecture. This was Bernal's major endeavour. During the interwar period, the need for new housing and planning policies, the establishment of a new research agenda for the building industry, advances in scientific war shelter, and a desire to unify disciplinary fields, found, first in Desmond Bernal, and later in Leslie Martin, a common vision and spirit of change.

## 7.2 02

The intellectual bond between Leslie Martin and Lionel March was fundamental to the introduction of quantitative ideas within the Cambridge School of Architecture, and at graduate level at LUBFS. The work conducted at the Martin Center in its different groups brought together architects, engineers and computer scientists whose pioneering research was essential to new areas such as environmental studies, CAD systems, and to the development of modelling techniques to address urban and planning problems. This assemblage of knowledge was further enhanced within the Center for Configurational Studies at The Open University, at Milton Keynes, UK, which for a period of 10 years functioned as a new theoretical and applied lab for the testing and development of many of the previous research projects.

The Center for Configurational Studies could thus be seen as a research interface between Continental ideas and those, which would soon emerge on the other side of the Atlantic. With the premature departure of Chermayeff to Harvard in 1940, by Alexander in the mid-50s and in the late 70s by Bill Mitchell, George Stiny and Lionel March to UCLA, the interest in generative computational applications to architectural design in the UK came to an end and while new ideas would be put into practice, first at UCLA, and later at MIT, emphasis in the

UK, was placed on the development of models that could assist an environmental design practice.

In the USA, the research initially conducted by Herbert Simon and later by Chuck Eastman at the DRC, pioneered a computational path that in many aspects was complementary to the work undertaken at LUBFS. However, there were fundamental differences between the LUBFS and the DRC research programs. While the former was interested in gaining fundamental knowledge about which new methods could be used and developed as models to improve built form, the latter was primarily concerned with the construction of a more scientific theory of design which, as mentioned before, was very much grounded in the idea of information process theory and in AI techniques. Despite differences, both Centers were responsible for the diffusion of a particular set of ideas and theories that proved essential to the increase of further research in the field of 'design and computation'.

In this regard, this work argues that recent developments on computational theories of design are the outcome of a larger theoretical framework that started to be developed in the mid 60s, both in the UK and in the USA.

### 7.3 03

The establishment of a system of knowledge in the light of the shift from print to electronic media brought consequences to architecture that go far beyond Walter Benjamin's thesis regarding the autonomous veracity of the reproduction of the work of art. Essentially, with the use of computational 'generative systems' in architecture, a new "aura" can be achieved. The introduction of new digital paradigms into architecture culture has shown a new misfit between theory and practice; a theoretical misfit that besides being chronological contemporary to the offspring of "critical theory," was mainly neglected by both historians and architectural theoreticians. "Critical theory" was the final offspring of a philosophical project that while defragmenting itself, witnessed at the same time, the birth of new branches of architecture theory. These new theoretical concepts which were very much oriented towards a computational application, rapidly clustered in specific theoretical rhizomes that represented a new paradigm in the creation and understanding of theory.

Moreover, the notion of the relationship between technology/science and architecture/scientist had been evolving since the 15c, but the idea that the architect is the sole master of architecture was rarely threatened. Nowadays we are still witnessing this conservative attitude towards the role that an architect should have. The revolutionary and metaphorical shift from 'machines' to 'computers', as one of the principal paradigm shifts that occurred in the 60s, led to the notion that the construction of the "machine" is an architectural process too. In this context, as new forms and discourses start to emerge, architectural criticism has to embrace computational processes, as it cannot be detached from the particular set of principles that underpinned these paradigms.

The architect and mathematician Lionel March already in 1972 pointed out the capabilities of modelling as a driven conceptual tool able to unify these cultures. He said: " Its now possible to represent a proposed design in mathematical terms [...]. In this form, the engineering model [model to improve practice] becomes compatible with the related scientific models [models to aid the understanding of a system], a direct coupling between the art and the science becomes possible, and the two unifying paradigms - the computer program and the mathematical model – themselves unite."<sup>231</sup> Today, the characterization of these procedures evolve the design of 'generative systems' which proves to constitute a method for the pursuing of research and practice in this area. The coupling of 'optimization' techniques, for the generation of form with other software[s], for its evaluation, seems a potential platform for generative design. However this implies knowledge in how to select and combine different computational techniques that can best express the architect intentions. This dissertation attempts to address this issue by re-examining the role of theory, seen here as catalysts to better relate the "two cultures" of architecture.

The question is not so much to inquire what architecture is, as to question what the role of an architect is in a contemporary computational and culturally networked society and practice.

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<sup>231</sup> March, L. [1972, March]. "Modern movement to Vitruvius: themes of education and research," *RIBA Journal* 3, 108.

## Appendix

## Introduction

This appendix succinctly illustrates three case studies in the area of generative design. It does not pretend to highlight a review of work developed on this theme, but rather to exemplify the use of one main computational strategy [Optimization] in generative processes of design.

Part of the difficulty of using optimization generative tools in architectural design is defining proper evaluation criteria, as population of candidate solutions to a given problem have to be evaluated according to a specified value. Optimization processes can be briefly described as a cycle in three-step process. The first consists of a generation of a population [chromosome] where the GA acts as the search and optimization engine; the second step performs the evaluation according to the objective function and gives a numerical value –fitness value- to each chromosome in each population and at the same time ranks the obtained solutions; the third phase consists in communicating this value to the search engine, which will ‘run’ a new search series.

The first and second case study on this appendix shows the appliance of a Genetic Algorithm [GA]<sup>232</sup> to the search and generation of design solutions for an architectural context. Whereas the first example runs within a known architectural context, Alvaro Siza’s School of architecture at Oporto, Portugal [Caldas, L and Rocha, J, 2001], the second case [Caldas, L, 2002], takes place in a non-defined corpus of design and extends the computational method into the domain of 3D form manipulation. The third case study displays the result of an experiment that combines the use of two different Generative Systems [GS]. One that uses an optimization procedure - coupling of simulating annealing, with a shape grammar as the search and formal mechanism - [Shea, K and Cagan, J, 1998] with other that employs Lindenmayer systems<sup>233</sup> and a simple grammar to simulate biologic growth and form finding [O’Reilly et all, 2000], [Fig. 011].

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<sup>232</sup> In the mid 60s the American computer scientist John Holland, created Genetic Algorithms [GA] [Holland, 1962], thus introducing the notion of ‘adaptation’, ‘evolution’ as an inspiration for solving computational problems. GAs began to be seen as a theoretical tool for investigating phenomena generated by complex adaptive systems [collective designation for non-linear systems defined by the interaction of large numbers of adaptive agents], such as economy, political systems, ecologies, immune systems etc.

<sup>233</sup> Lindenmayer systems [L-systems] are a mathematical formalism proposed by the biologist Aristid Lindenmayer in 1968 as a foundation for an axiomatic theory of biological development.

## Case 01

The objectives of this case experiment were twofold: first, to study the incorporation of architectural language constraints into the generative design system, so that solutions generated are within [or not] certain design intentions. Second, to examine the generative system results from the perspective of the existing design by the architect Álvaro Siza.

Due to the need to find elements that would lead to the development of a method to understand and encode Siza's design intentions, analysis of the drawings and a visit to the building allowed us to infer design rules that were applicable to the existing elevations. In this case we are operating within a given architectural context. The inferred rules relate both to compositional axes of the facades and to general proportions of the openings ["constraints"] [Fig. 03]. For the existing building layout [fifth tower of the general plan] [Fig. 01] the software generates a population of façade solutions that takes into account the use of day lighting in the space, the use of artificial lighting, and the energy consumed to heat and cool the building. Generated solutions try to respond as the best solution to these variables but should not be regarded as an optimum response to a given problem. Instead, they should be taken as useful information on the overall interaction of different elements of the building that may provide guidance for further developments during the design process.

In this study we used environmental analysis as a particular field for goal-oriented design, because it is possible to specify quantifiable performance criteria to be achieved with the design. The GA works as a search and optimization tool, DOE2.1 [building simulation software], simulating the behavior of each solution in terms of its use of natural lighting, thermal performance [heating and cooling] and yearly energy consumption [MW/h]. The generative system works over a full three-dimensional description of the building - its geometry, solar orientation, internal organization, construction materials - and the algorithm's search space was left to elevation design solutions only [Fig. 02].<sup>234</sup> The problem under study is complex due to the number of dynamic interactions occurring between all variables but the GS is able to operate upon these variables, generating, evaluating designed solutions and providing a range of other technical information regarding the building performance in terms of energy use.

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In this study, building geometry, space layout and construction materials were left unchanged. For further work see, Caldas, L. [2002]. "Evolving Three Dimensional Architectural Form," in J.S. Gero, [Eds], *Artificial Intelligence in Design' 02*, Key Center of Design Computing and Cognition, University of Sydney, Sydney. Kluwer Academic Publishers, 351-70.

Results from this experiment, ranged from an almost exact coincidence with Siza's solutions to some radical departures from the existing design. In the south orientation [Fig. 03] the generative system solutions present more significant modifications in relation to the existent. North elevations show significant changes particularly for the best-fit solutions [Fig. 03]. A comparison between the existing building and the best solution suggests that the GS performed well within the given design constraints [Fig. 05].<sup>235</sup>

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<sup>235</sup> The authors would like to thank William Mitchell, Álvaro Siza and Peter Testa for their kind support during the elaboration of this research project.

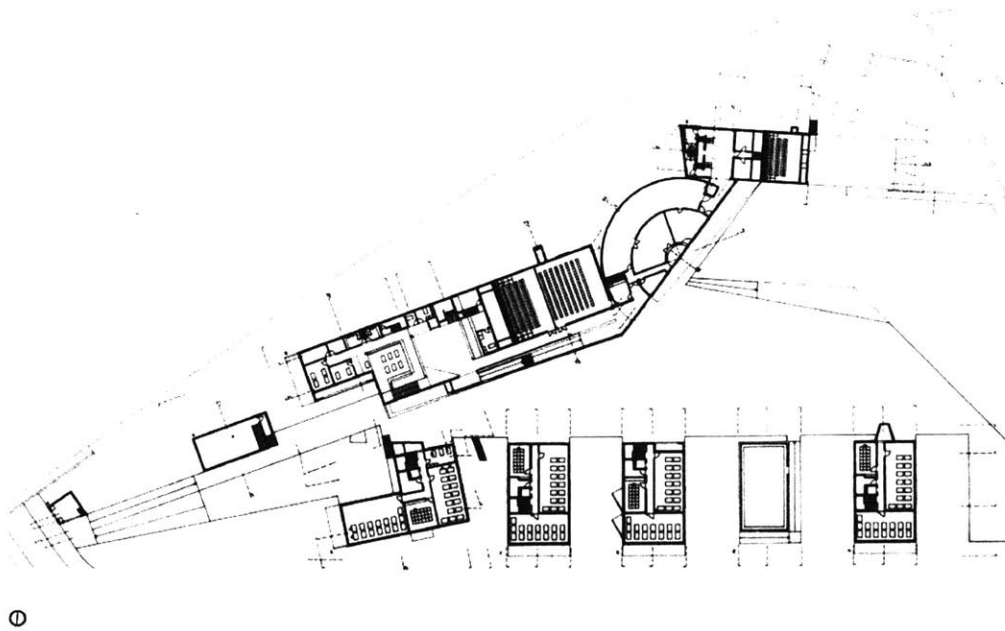
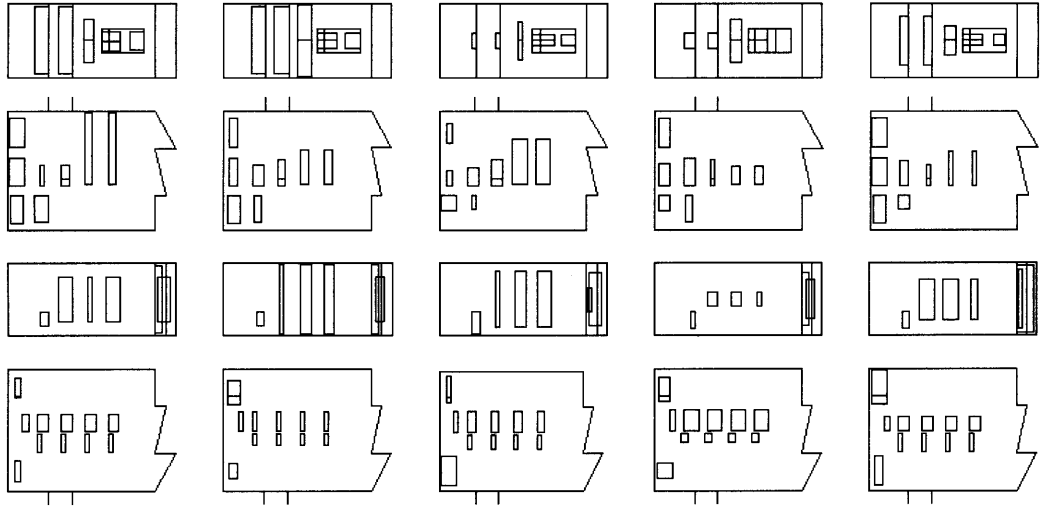


Fig 01. Oporto school of architecture general plan by Álvaro Siza, [1984-96].

[p 104]



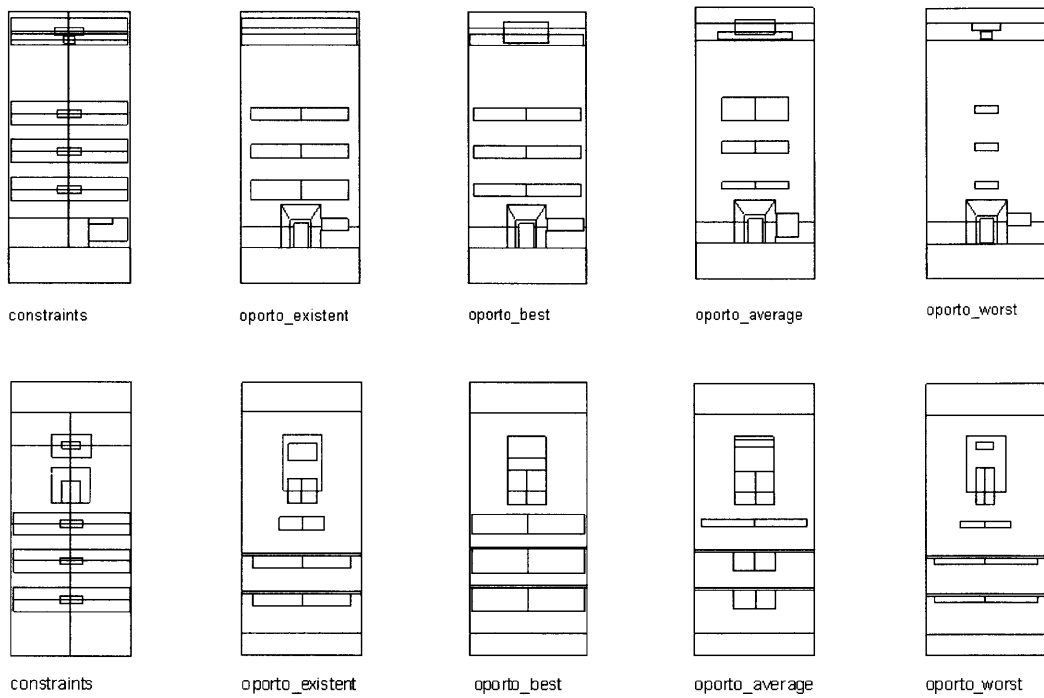


Fig 03. Range of GAs solutions for Oporto. North [row above] and South [row below] elevations. [p 104].

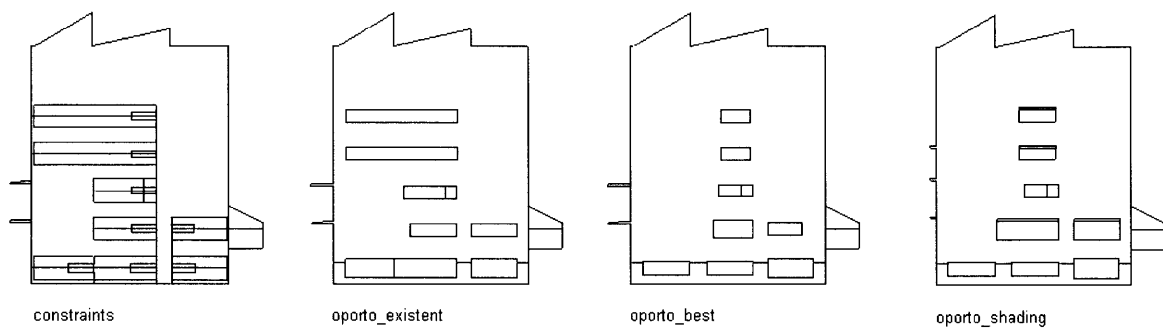


Fig 04. Randomly GAs solutions for the East façade.

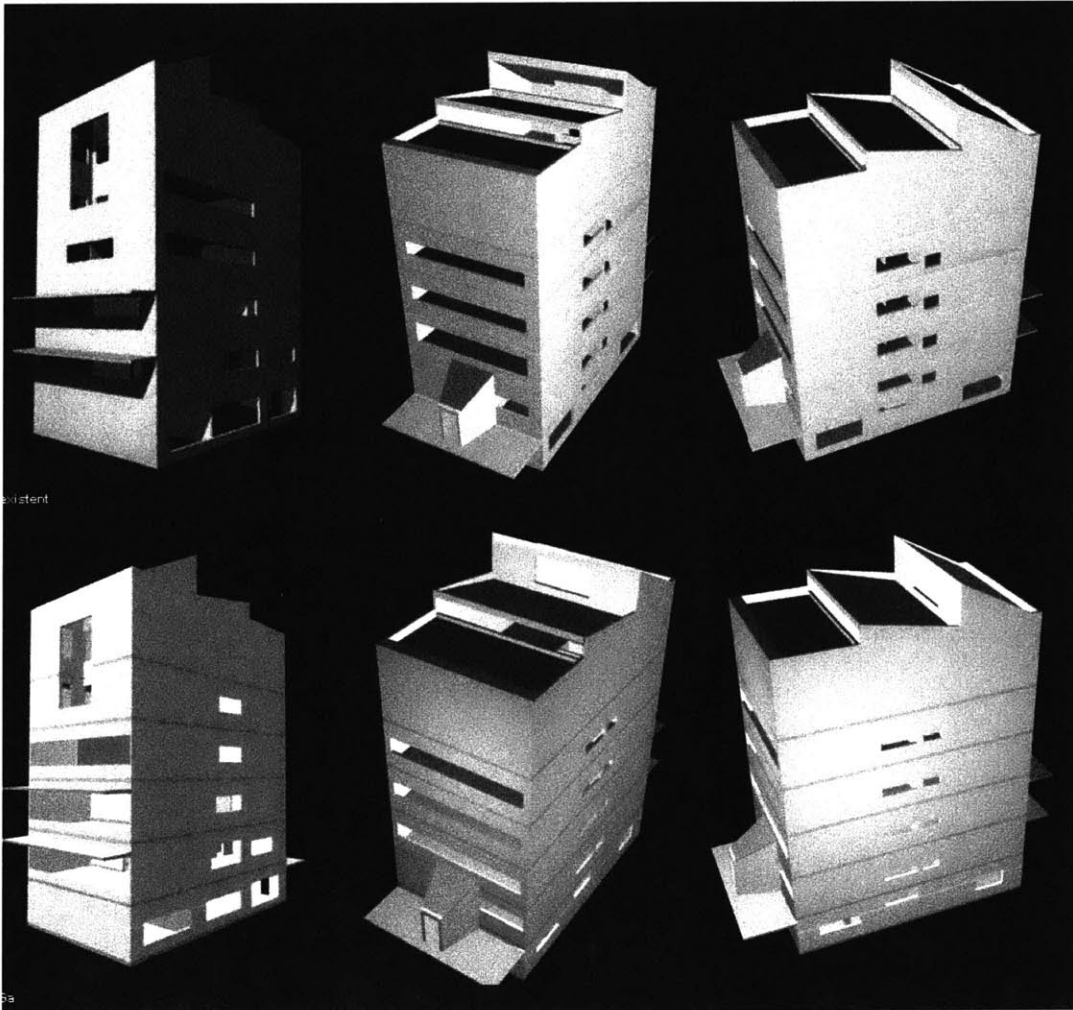


Fig 05. 3D comparative results between the 'best' GA solution [row below] with the existent building [row above], [p 105].

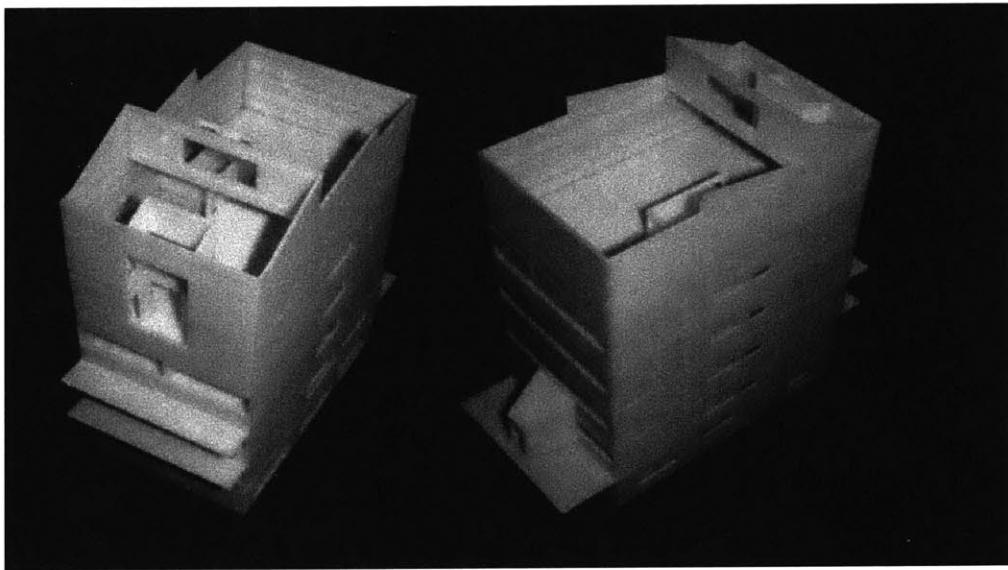


Fig 06. 3D Printing of the 'best' GA solution. [FDM model].

## Case 02

In this case the design problem was conceived only in terms of abstract relations between different elements. [Caldas, L 2002]. Four cubic volumes, repeated in the z direction [Fig. 07; Fig. 09], simulate floors, where constraints are related to the height and width of each, and to their maximum and minimum dimensions. In this experiment, because there are not a previous corpus of design from which design rules could be inferred, the criteria do establish compositional axial constraints - an important feature as they encode architectural intentions - where left this time to the author's architectural intentions. This constitutes a different setting, as the set of criteria to begin the generative process is open to many possibilities, both conceptually [the abstract volume search space for form manipulation] and theoretical [axial constraints, facades design and tilt walls].

Again, adaptation of form is directed towards environmental behaviour, search for designs that best harvest day lighting and reduce thermal exchanges with the exterior environment. In these experiments, a major concern for the reduced consumption of energy would be achieved by the reduction of the building area. The GS had to solve the problem of finding the best trade-offs between design solutions that offered good daylighting and at the same time, minimized the need for heating. Energy consumption operating as the objective function suggested that the population of design solutions would be of minimum dimensions with different facades and roofs. In this case a multi criteria optimisation procedure was taken in order to run the GS. GA's are usually used for single-criterion optimisation problems, but there are a large set of problems that are multi-criteria in its essence, and these multiple criteria should be optimised at the same time. Here, Pareto method was used as it allowed for search experiments within a Multi-objective optimisation [MOP] problem. A Pareto solution is optimal if it is not dominated by any other solution. Fig. 08 shows [row below] results in terms of best solution on terms of lighting, as the Pareto run was performed for two objective functions, both minimizing energy spent in lighting, and minimizing energy for heating. Computing with climate data for Oporto, Portugal, and Chicago, USA, the GS created a variety of architectural solutions responding to the specificities of each location, where volumetric variations as well as façade designs change accordingly to the heating gains [Fig. 08].

The results are a consequence of how the initial problem was set up, and the architect's intentions that frame the specificities of the constraints. The process embodies a complete cycle of computational and theoretical decisions [Fig. 09].

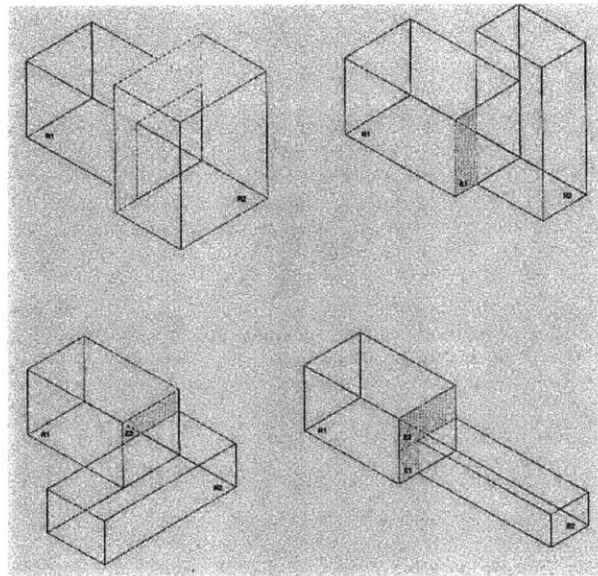


Fig 07. Conceptual and diagrammatic scheme showing the inter-relationships between external, interior and adjacent walls, [p 114].

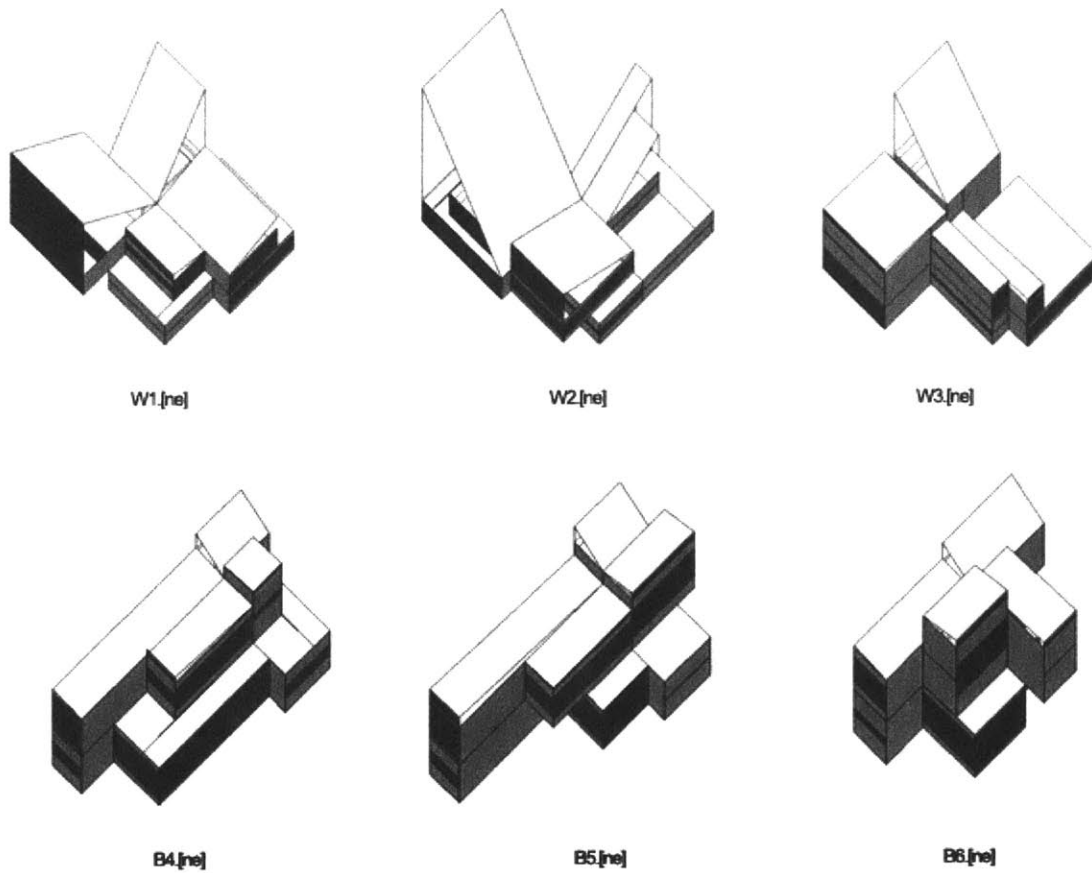


Fig 08. Range of 'best' solutions [row below] [MOP], and 'worst' solutions [row above] for Chicago, using Energy Use Intensity [EUI] as fitness function. Darker areas in the façade represent windows. [NE, facades], [p 114].

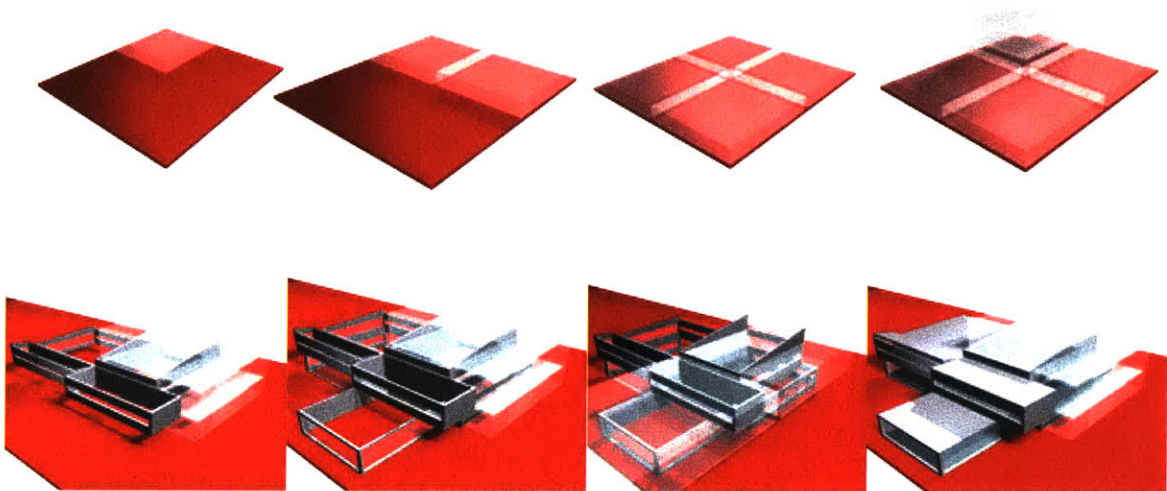


Fig 09. 3D simulation of 'form' evolution for the 'best' GA solution for Oporto climate. The row above shows the basic square scheme, which is divided into four smaller squares each one correspondent to one room. Each room can vary in length and width, but constrained to have the same height [ground floor]. In the 1<sup>st</sup> floor, space could vary in height and roof tilts could vary from 0° to 90°, [p 115].

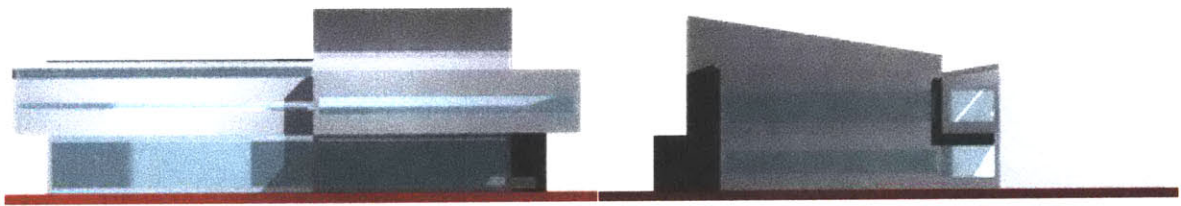


Fig 010 . GA 'best' South and West facades.

### Case 03

This example connects the results of form generation through the use of two different computational platforms. One is based on a generative structural software, eifForm [Shea and Cagan, 1998], which makes use of the shape annealing method<sup>236</sup> as the generation engine for structural designs. eifForm combines a shape grammar that defines design constraints according to certain topological rules and evaluation is performed by finite element analysis. The search for design solutions takes place through a constrained space of structures by the manipulation of several parameters such as: number of truss members, area, number of rules to be applied, truss thickness, etc.

The other generative platform, MoSS - Morphogenetic Surface Structure - [O'Reilly et al, 2000] is based on simple grammar rules that define an initial shape that evolves by defining free form surfaces. MoSS works as a conceptual tool where L-systems allow form generation, which is essentially controlled by a context free grammar that is based on a set of rules that are serially applied to an initial axiom. The 3D environment where this surface emerges has features [repellers and attractors], which also influences the shape and growth that takes place within it.

MoSS and eifForm were used as testing platforms in a design studio at MIT,<sup>237</sup> and the selected work shows a glazing façade created with MoSS whereas its structure was formed by the use of eifForm [Fig. 012].

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<sup>236</sup> Simulated annealing is based on the analogy between the process of the annealing of solids and the problem of solving combinatorial optimisation problems.

<sup>237</sup>

Design Studio of the Future [DSOF], Fall 1999. [Profs: Bill Mitchell and Peter Testa; TAs: Axel Kilian and João Rocha]. Work carried out by Luke Yung.

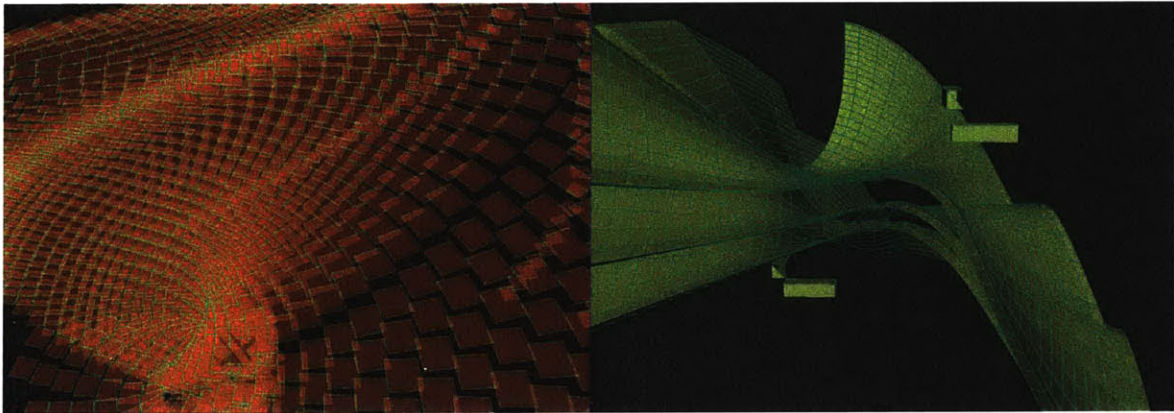


Fig 011. Generic configuration of a 3D MoSS' environment. Image on the left illustrates one basic rectangular grammar and its evolution by L-Systems; image on the right shows repellers and attractors as agents that modify the generated form. [Image by: Markus Kangas, Janet Fan and Axel Kilian], [p 105].

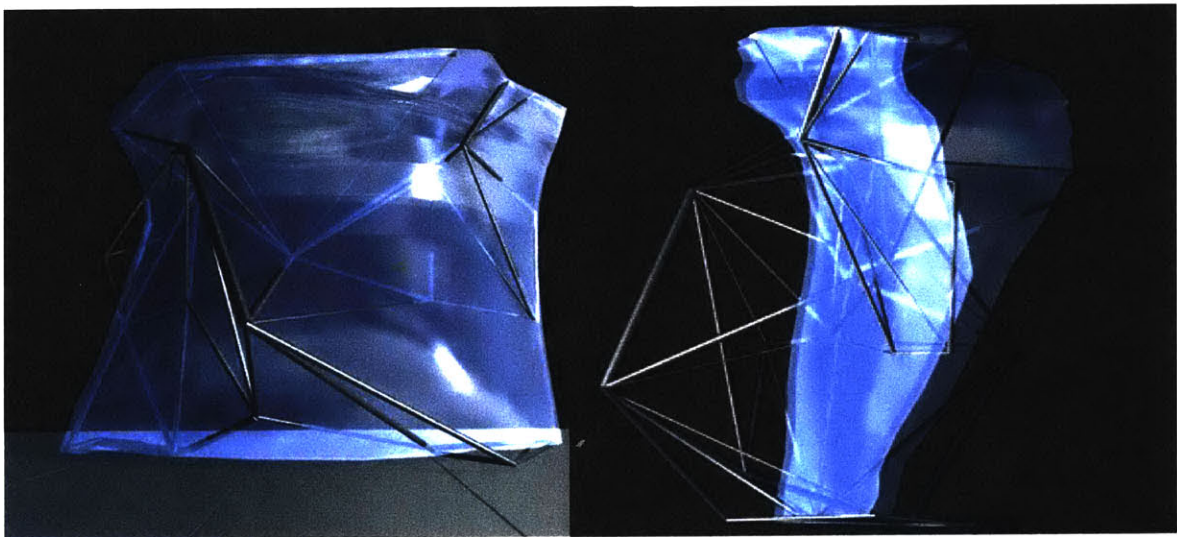


Fig 012. The coupling of MoSS [glass surface façade], with eifForm [metal structure] as the outcome of an experimental architectural experiment. [Work by Luke Yung, DSOF], [p 120].

**Documents from Archives . Photographs and figures.**

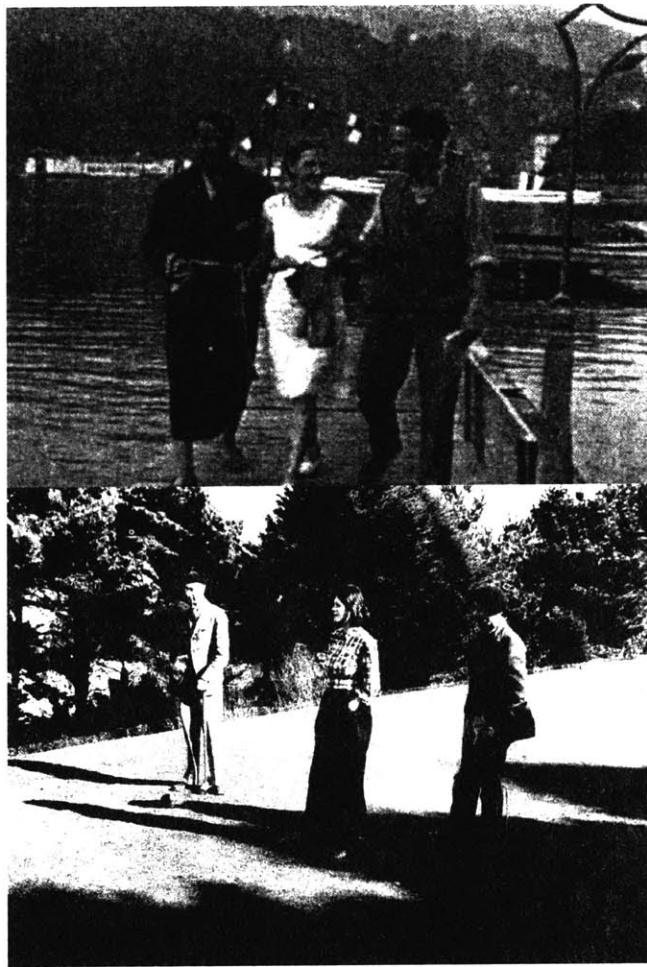


Fig 1. Prascovia Schubersky [center], Berthold Lubetkin [right] [c.1930].

[p 42]

Fig 1a. Herbert Read [left], Margaret Gardiner [center] and Ben Nicholson [right] at Carbis Bay [c.1942].

[p 42]



Fig 2. Herbert Read at n.3 Mall Studios, Hampstead, London [c.1930].  
Fig 2a. Naum Gabo in his studio at St. Ives, Cornwall [c.1944].

[p 46]  
[p 48]

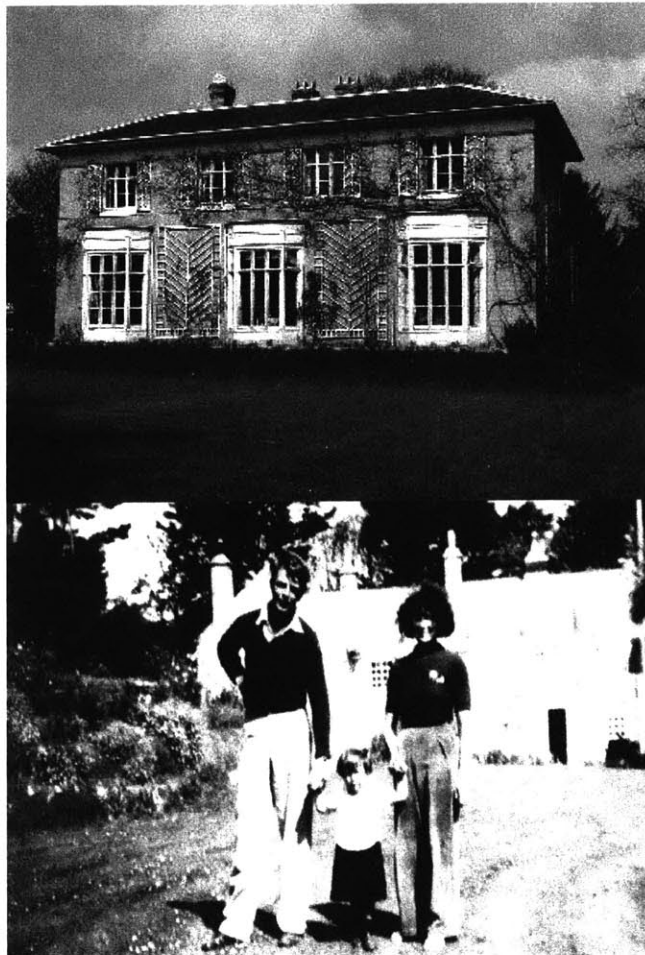


Fig 3. 'Finella', Cambridge [c.1940].

Fig 3a. Adrian Stokes and Margaret Mellis, at Park Owles, Carbis Bay. Cornwall [c.1941].

[p 44]

[p 44]



Fig 4. Berthold Lubetkin and Ove Arup. High Point One, Highgate, London [1932-35].

[p 51]

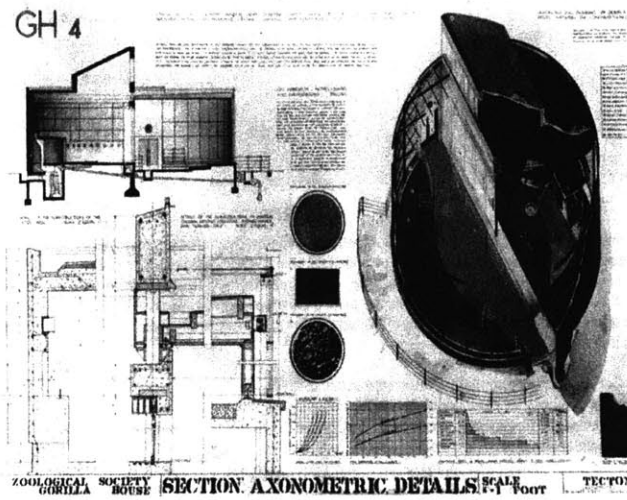
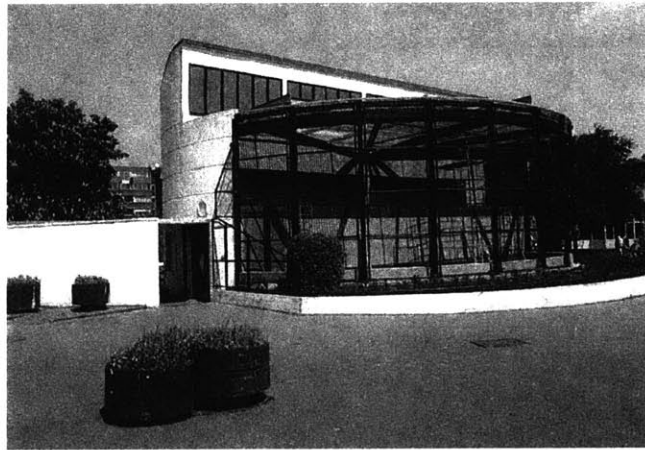


Fig 5. Berthold Lubetkin and Ove Arup. Gorilla House, Regent's Park, London. [1932-33]  
Fig 5a. Gorilla House, construction drawings.

[p 58]

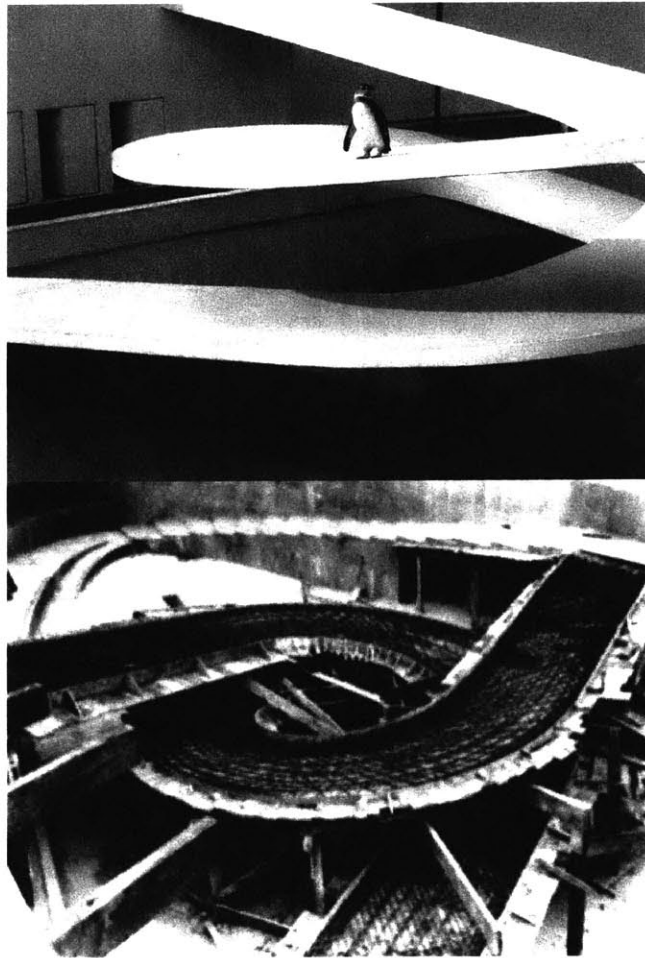


Fig 6. Berthold Lubetkin and Ove Arup. Penguin Pool, Regent's Park, London [1934]  
Fig 6a. Berthold Lubetkin and Ove Arup. Penguin Pool, Regent's Park, London [1934]

[p 58]

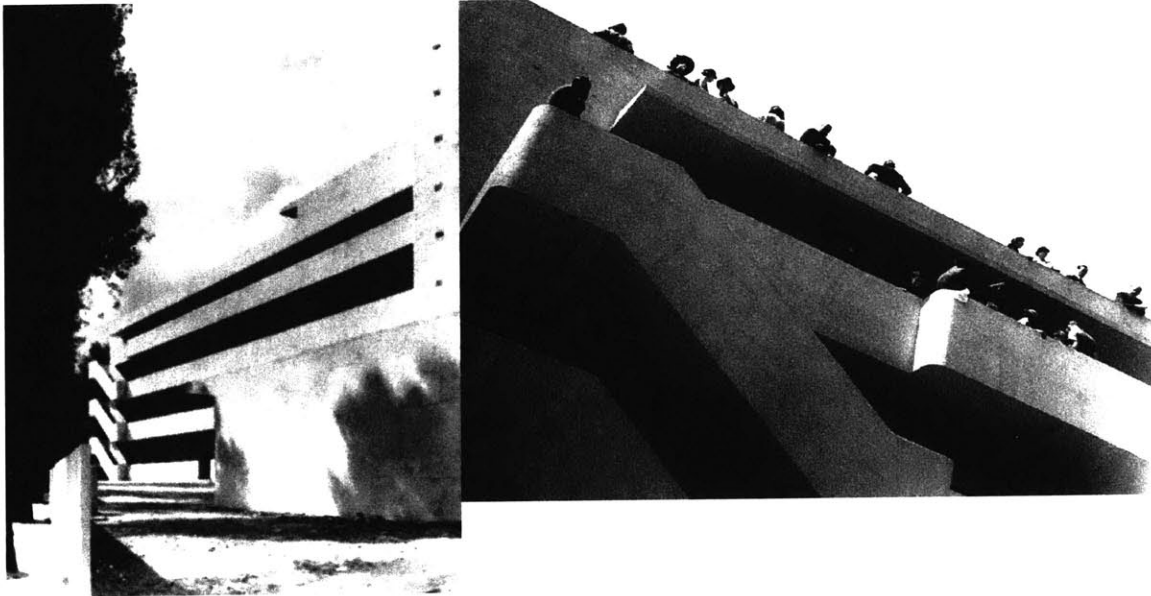


Fig 7. Wells Coates, Lawn Road Flats. Hampstead, London [1931-33]  
Fig 7a. Opening day at Lawn Road Flats: 9 July 1934.

[p 59]

<u>Sent to:-</u>	Emberton				
Gibberd	Goldfinger				
Lubetkin	Holford				
Shand	Moholy-Nagy				
Yorke	Miss Blanco White				
Arup		M	A	R	S
McGrath					
Chermayeff	Modern Architectural Research				
Tatton Brown					
Winser		G	R	O	U
Scholberg					
Godesmith					
Chitty					
Nicholson					
Coates					

January 16th 1937

Dear

Mars Exhibition

Arrangements for the Mars Exhibition at the New Burlington Galleries in June 1937 are going rapidly forward now. The brochure which has been prepared will be submitted to Patrons next week.

The next stage consists in the approach to Manufacturers Associations for support in money and kind, and we are anxious to cover the field as widely as possible through Mars members, and to approach Associations through prominent Manufacturers who are sufficiently keen to be able to persuade their Associations of the importance of the Exhibition. The Committee feels that your knowledge of the building industry is peculiarly valuable and would be glad if you could let us have names of any individuals or any other channels through which you think Associations could be approached. This information should be sent to the General Secretary at 55 Gordon Square, W.C.1., to reach him by not later than Saturday, January 23rd.

It would greatly help the Committee if you would follow this up by attending the Group meeting on February 4th at 8 o'clock at 55 Gordon Square, W.C.1., when the next stage of the work will be proceeded with.

Yours very truly,

Gen. Secretary  
For the Executive Committee.

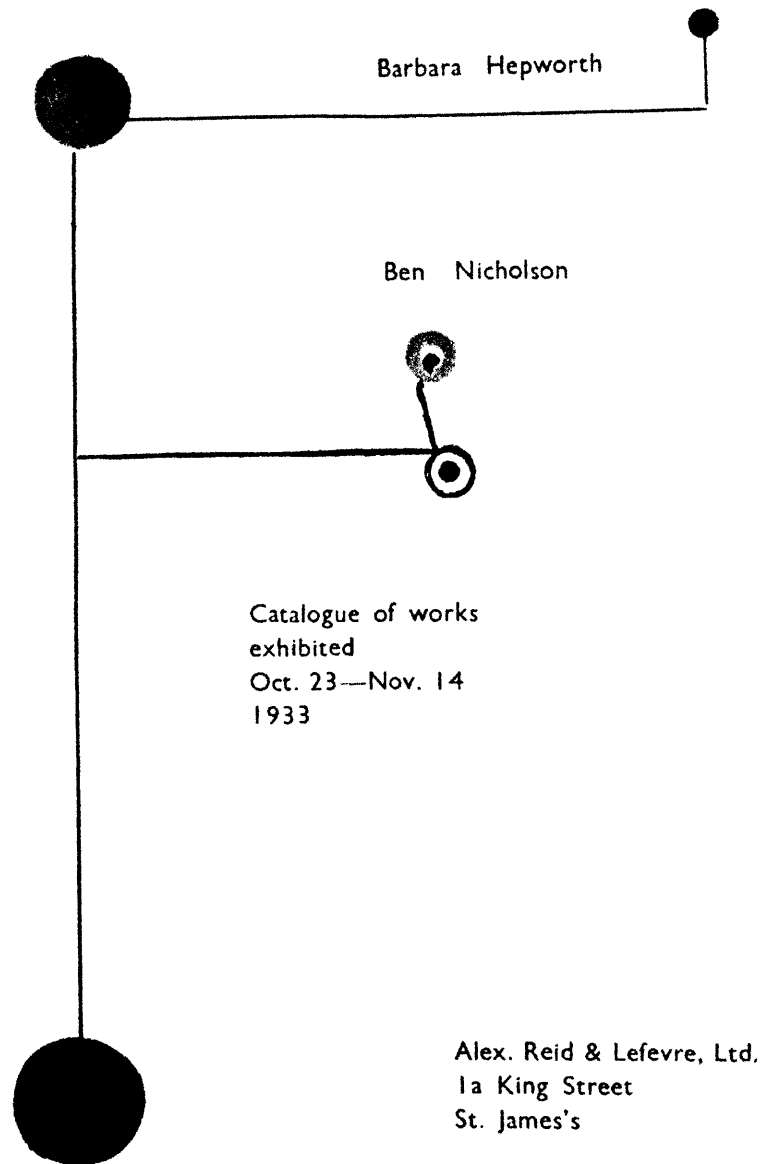


Fig 9. Catalogue cover of exhibition held at Reid and Lefevre Gallery [1933]

[p 46]

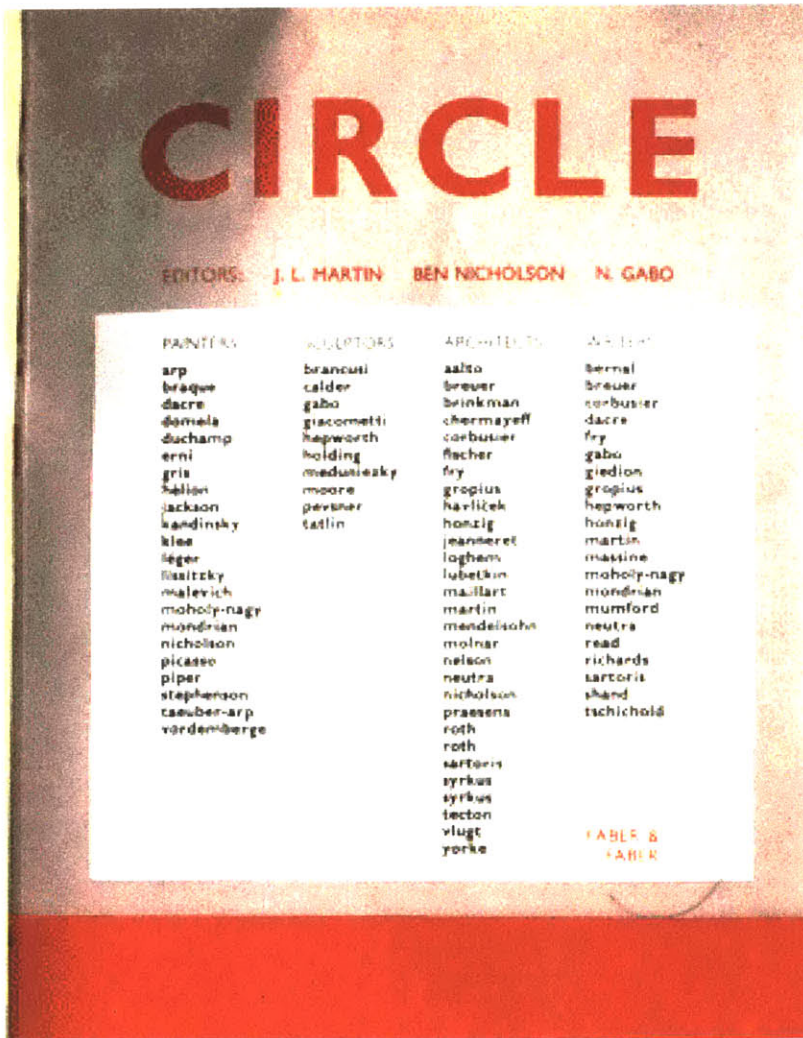


Fig 10. Cover of *Circle*, [1937].

7 The Mall Studios  
Parkhill Rd  
NW3

Dear Desmond

Do you think you could possibly write a foreword to my Exhibition Catalogue? I have been trying to screw up the courage to ask you for some days because I realise how many demands are made on you + far more important demands than a foreword. It need only be very short (500 words) - and if you could possibly manage to do it - it would be of the greatest help. All this sounds very personal; but actually it need not be so personal - it is really an opportunity to say a few words in support of an idea.

Fig 11. Barbara Hepworth letter to Desmond Bernal. [1937] [three page document].

[p 50]

## FOREWORD J. D. BERNAL, F.R.S.

This appreciation of the sculptures exhibited by Miss Hepworth is not to be taken as an aesthetic criticism. It simply expresses the relation of an extremely refined and pure art form to the sciences with which it has special affinities. The first impressions of the present exhibition suggest very strongly the art of the Neolithic builders of stone monuments which, in the second Millenium, stretched along the coasts from Sweden to Assam. Nor is the analogy entirely superficial. Neolithic art with its extreme formalism does not represent a primitive stage in the evolution of art, but an apparent step backwards away from the admirable and living representations of the art of the Cave painters. This backward step is illusory, for Neolithic art is highly sophisticated and expresses the realisation that important ideas can be conveyed by extremely limited symbolic forms: that it is unnecessary to fill in details as long as general intentions are realised. In a sense Miss Hepworth's art stands in this extreme relation to the representational art of the nineteenth century from which the whole of present century art has been in revolt. She has reduced her sculptures to the barest elements, but these elements correspond curiously enough so closely with those of Neolithic art that it is in comparison with them that we can best describe them.

The largest group of sculptures are the upright blocks corresponding to the Neolithic Menhirs which stand through Cornwall and Brittany as memorials to long forgotten dead. Another group represents stones pierced in one way or another with conical holes. Such stones occur in the Dolmens themselves, supposedly to furnish a means of egress for the soul. The most famous of them in Cornwall, Men-an-tol, may be chosen to give them a name. Further resemblances occur in the cup markings and the loose stones which sometimes fill them whose ritual purpose is still unknown, both of which are here amply represented. Finally, the problem of the relation of two uprights or two spheres, many solutions to which are offered in Miss Hepworth's art, correspond on a limited scale to the great alignments and rings of stones which mark the central shrines of the Megalithic world. It would be wrong however to say that Miss Hepworth is simply re-creating a lost phase of art, such certainly has never been her conscious intention. Indeed in other ways her statues correspond to the earliest stage of Greek sculpture recalling many Helladic figures and particularly early statues of

Fig 12. Desmond Bernal's foreword for Barbara's catalogue exhibition [1937] [ three pages document ]

[p 50]

Do try to see Gabos new construction - it is very fine  
7 MALL STUDIOS PARKHILL ROAD NW3 LONDON GULLIVER 2265  
& I think you'd like it as much as I do 2/5/39  
dear Desmond  
I saw Margaret & she told  
me you had separated. I am  
so sorry.  
I do hope, though, that we shall  
not lose sight of you. We should  
both be particularly pleased if you  
would come to see us, whenever  
you have time - if you would  
care to. With best wishes Barbara.

Fig 13. Barbara Hepworth's card to Bernal [1939].

[p 52]

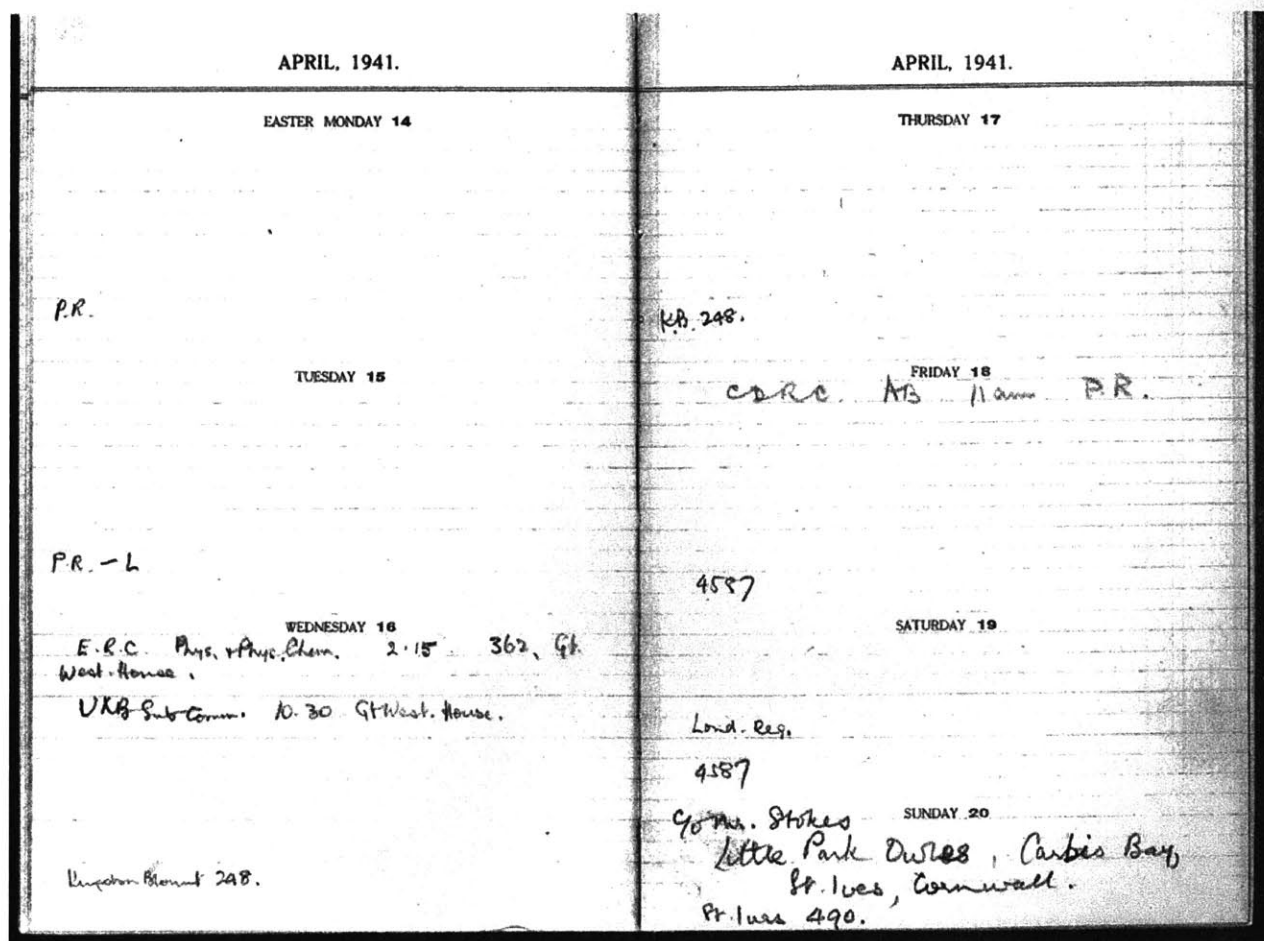


Fig 14. Desmond Bernal's diary [1941]. Bottom right page, showing that Bernal was close to Adrian Stokes. Visit scheduled to a Sunday, St. Ives. Carbis Bay, Cornwall.

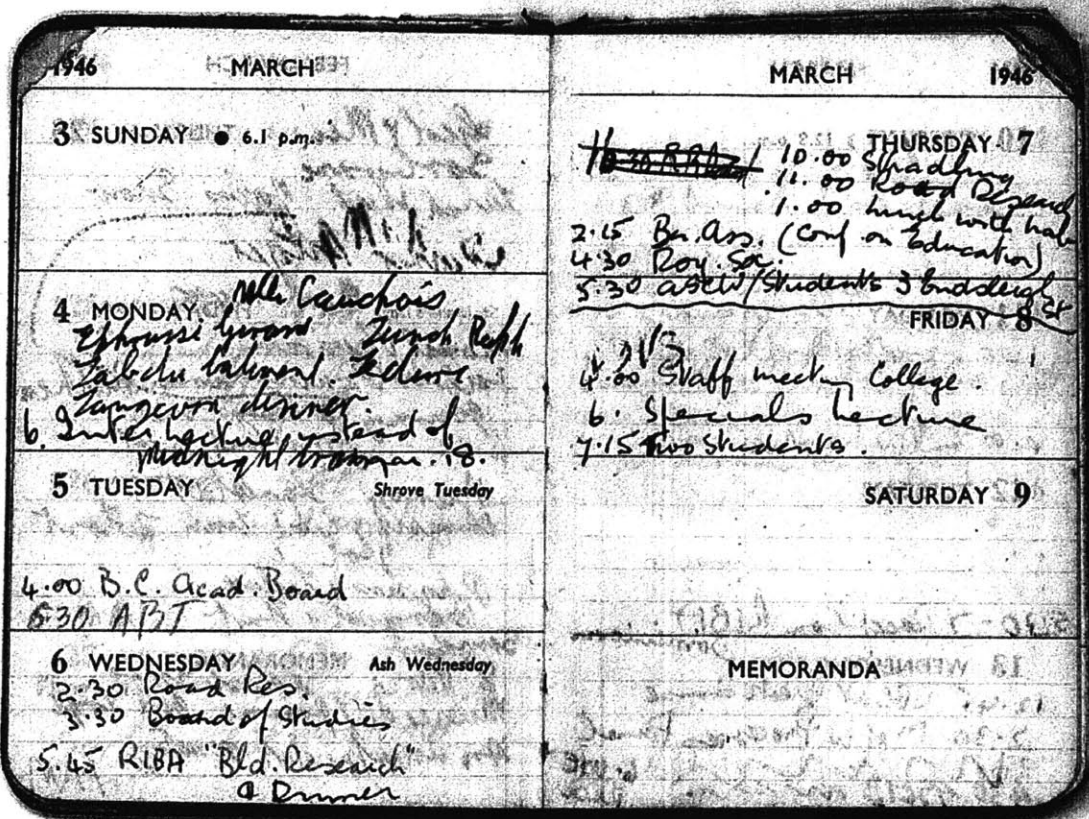
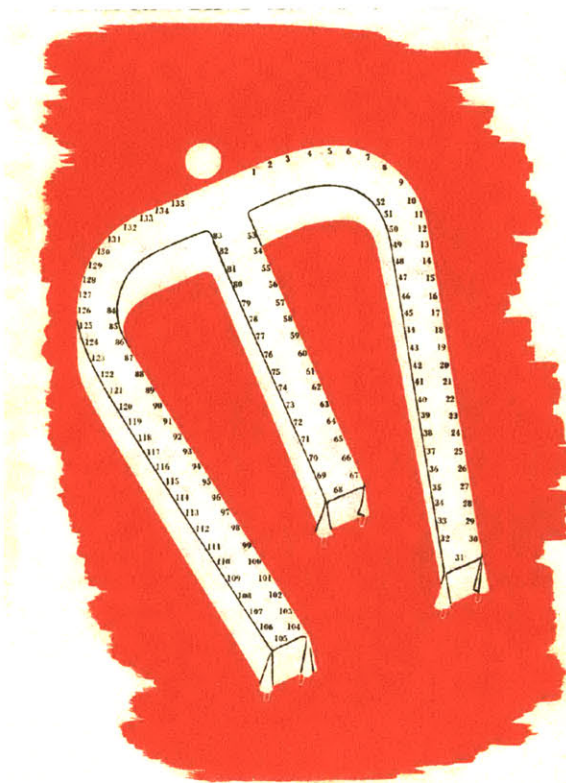


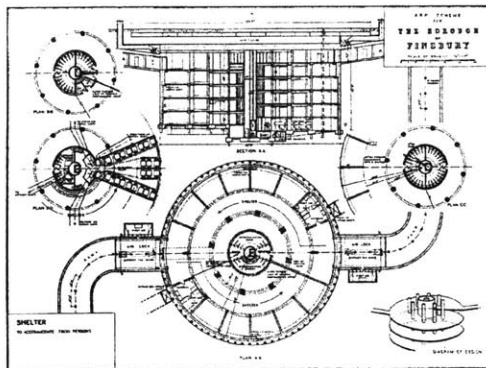
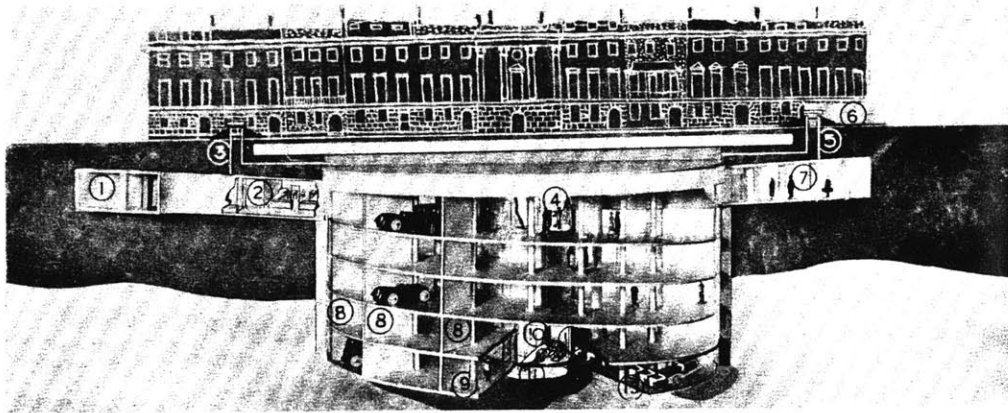
Fig 15. Desmond Bernal's diary [1946]. Bottom of left page, showing the scheduled meeting at RIBA. [p 72]



## ALPHABETICAL LIST OF GUESTS

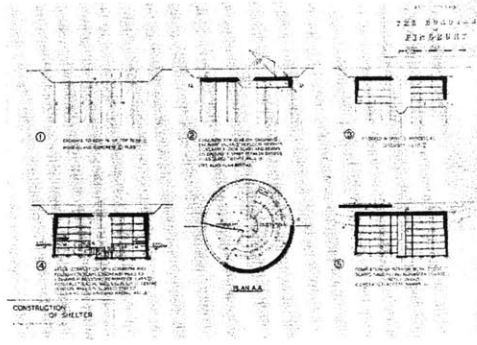
<b>A</b>	Professor Abercrombie	6	<b>F</b>	Mr. Ernst L. Freud	46	<b>M</b>	Mrs. J. Dawson Miller	21	
	Mrs. Patrick Abercrombie	106		Mrs. Ernst Freud	5		Professor L. Moholy-Nagy	72	
	Dr. Thomas Adams	127		Mr. E. Maxwell Fry	83		Mrs. Moholy-Nagy	132	
	Mrs. Mary Adams	67		Mrs. E. Maxwell Fry	88		Mrs. Henry Moore	47	
	Mr. E. W. Armstrong	84		<b>G</b>	Dr. Siegfried Giedion	66	Mr. Henry Morris	79	
	Mrs. E. W. Armstrong	102		Mr. John Glaz	17		Mr. H. G. Murphy	87	
	Mr. Ove Arup	25		Mrs. John Glaz	78	<b>N</b>	Mr. Christopher Nicholson	58	
	Mrs. Ove Arup	124		Mr. John Glaz	79		Mr. Max Nicholson	12	
	Mr. D. Aspid	109		Mrs. John Glaz	79		Mr. Clifford Norton	14	
	Mr. Ray Ashton	133		Mrs. John Glaz	135		Mrs. Clifford Norton	104	
				Dr. Walter Gropius					
<b>B</b>	Mr. B. Buss	95		Mr. Val Harding	15	<b>P</b>	Dr. N. Pevsner	61	
	Mr. D. Buss's guest	96		Mrs. Val Harding	58		Miss M. L. Pevsner	126	
	Mr. Eric L. Bird	18		Dr. E. H. Rippen	24		Dr. Arthur Upham Pope	36	
	Mr. D. L. Bridgwater	53		Mrs. Hargreaves	31		Mr. Fitzmaurice C. Pritchard	89	
	Mrs. D. L. Bridgwater	22		Mrs. Gillian Harrison	7		Mrs. Fitzmaurice C. Pritchard	41	
	Professor Lionel Budden	125		Mr. Ashley Harvilland	92		Mr. J. Crown Pritchard	36	
				Mrs. Ashley Harvilland	92		Mrs. J. Crown Pritchard	69	
<b>C</b>	Mr. William Cahn	94		Mr. G. Brian Heister	111	<b>Q</b>	Mr. Hugh Outley	90	
	Mr. Noel Carrington	152		Professor W. G. Huftard	29				
	Mr. Edward Carter	27		Mr. E. G. Hulford	9	<b>R</b>	Dr. M. Rothko	86	
	Mrs. Edward Carter	51		Dr. Julian Husley	3		Mr. A. E. Road	49	
	Mr. Cyril Carter	42		Mrs. Julian Husley	3		Mr. Herbert Road	68	
	Mr. J. Charles	112		Mr. Gilbert Inghelield	115		Professor G. H. Rolly	44	
	Mr. Serge Chermayeff	53		Mrs. Gilbert Inghelield	115		Mr. Paul Rolly	60	
	Mrs. Serge Chermayeff	28		Mr. R. T. James	92		Mr. J. M. Richards	11	
	Mr. W. H. Coates	64		Mrs. R. T. James	19		Mr. Michael Ross	59	
	Mr. J. M. Coles	62				<b>S</b>	Mr. Geoffrey Samuel	52	
	Mrs. J. M. Coles	62		Mr. H. Kallinbach	21		Mr. P. Martin Skand	8	
	Mr. Willard Coombs	55		Mr. E. Katz	129		Mrs. P. Martin Skand	26	
	Professor W. G. Coombs	105		Mrs. C. J. Keenan	101		Dr. S. Stebbins	76	
	Mr. George Cooke	59		Miss Gertrude Kalman	56		Mr. J. Dixon Symes	118	
	Mrs. George Cooke	122					Mr. C. D. Spragg	98	
	Mr. Graham Cunningham	97		<b>L</b>	Mr. R. S. Latham	33	Mrs. Cunningham Scott	110	
	Mrs. Graham Cunningham	119		Miss Judith Ludlow	40		Mr. John Sumner	27	
	Mr. E. Curtis	117		Miss Jane Liddell	13		Mrs. Cyril Swain	113	
	Mr. B. Curtis	116						91	
<b>D</b>	Mr. Hugh Dalton	32		<b>Y</b>	Sr. Ian MacAlister	31	<b>V</b>	Mr. R. Vaughan	114
	Mr. W. Davies	121		Lady MacAlister	134		Mrs. Doreen Vazir	75	
	Mr. Richard de la Mare	10		Mrs. Edward Manly	43	<b>W</b>	Mr. C. H. Waddington	49	
	Miss Elizabeth Denby	120		Mrs. J. E. R. McDonagh	100		Mrs. C. H. Waddington	73	
	Mrs. T. Donovan	183		Mr. Charles Marriott	121		Sir Alexander Walker	107	
	Mr. E. W. Dyer	129		Mrs. Charles Marriott	30		Lady Walker	130	
	Mrs. E. W. Dyer	34		Mr. Basil Morrison	99		Mr. Richard Wainwright	82	
	Mr. J. G. F. Donaldson	74		Mrs. H. G. Wills	65		Mr. H. G. Wills	2	
	Mrs. J. G. F. Donaldson	63		Mr. J. Dawson Miller	23		Mr. Clough Williams-Ellis	81	
<b>E</b>	Mr. Geoffrey Fisher	4							
	Mr. Alexander Forsytherson	77							
	Miss Ellen Frank	35							

Fig 16. Brochure of Farwell dinner to Walter Gropius, [1937].



152 Model of Bomb-proof Shelter (for 7,600 people)

153 Plan of Bomb-proof Shelter (for 7,600 people)



154 Construction Drawing

Fig 17. Over Arup and Tecton, *Sectional view of 'War shelter' for 7.600 people*, [1939].

**SERGE CHERMAYEFF F.R.I.B.A. ARCHITECT**  
CHARTERED AND REGISTERED

LONDON SW1 19 GROSVENOR PLACE

SLOANE 9129

30th January, 1939.

SC/CI

Godfrey Samuel, Esq.,  
6, Cavendish Square,  
W.1.

Dear Godfrey,

Since I last saw you a large number of signatories have been obtained among working Scientists for the enclosed Memorandum, among them, Holford, Bernal, Haldane, Sir Arthur Salter, also Samuely who gave me a lot of assistance.

I want to obtain not only individual signatures, but M.A.N.S., so that M.A.N.S. can indirectly get some of the publicity which is going to be given it by the Daily Express and publication.

Unfortunately I shall not be able to attend the General Meeting as I am giving a lecture that night. Could you read through the Memorandum and ask the Executive of M.A.N.S. to back it on behalf of the Group at the meeting, even against possible protests from the M.A.S.T.A. opposition? I think it is very important.

Yours,

*Serge*

*before  
on phone  
talk  
SC*

Fig 18. Serge Chermayeff letter to Godfrey Samuel [1939].

[p 69]

WESTERHAM 93.

CHARTWELL.  
WESTERHAM,  
KENT.

20 March 1939

Dear Sirs,

I am desired by Mr. Winston Churchill to thank you for the book "Planned A.R.P.", which you have sent him.

Mr. Churchill has to-day studied this book with some attention, and has not been favourably impressed thereby. It appears to be inspired by a wish to exaggerate the dangers of air attack and to emphasize the futility of basement protection in the interests of some particular scheme with which you are associated. The wide circulation of such a book would not be helpful at the present juncture.

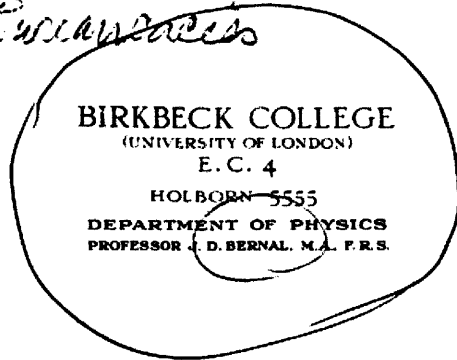
Mr. Churchill understands from the Lord Privy Seal that properly reinforced basements will give a very large measure of protection.

Yours faithfully,

*O. Harrington*  
Private Secretary.

B. Lubetkin, Esq.,  
Tecton.

3 = *Lucas*



ADVERSE IMPACT  
COLUMBIA UNIVERSITY

15th. March, 1940.

Dear Serge,

I was very glad to hear that you had got through the dangers of the crossing.

Robert L. Davison's address is:

John B. Pierce Foundation,  
Research Department,  
40 West 40th. Street,  
New York.

I think he would be very interested in your ideas.

We are having great fun here with the Science Committee of the R.I.B.A., which was set up with a great flourish of trumpets. The R.I.B.A. afterwards got cold feet about it and decided that all our suggestions would have to be veted by another committee of senior architects. We are not having any at the moment but whether we can make them climb down is still uncertain.

Yours sincerely,

*Desmond*

Fig 20. Desmond Bernal's letter to Serge Chermayeff [1940].

MARTIN AND SPEIGHT . REGISTERED ARCHITECTS

8 THE PARK HULL  
TEL. CENTRAL 7398

Godfrey Samuel Esq.  
Chairman, Mars Executive.

8.10.38

Dear Samuel,

I am so sorry that I have not been able to reply to your letter before this, and I very much hope that my delay has not caused you any inconvenience. I was very interested to hear that there is a chance that the Mars Exhibition will be sent on tour especially as there is a possibility of showing it here under very favourable conditions in March next if this is not too late. During that month we shall hold the Congress of Northern Architectural Students in Hull; I expect that there will be about 200 students from various schools in the north of England and naturally there will be a certain amount of public interest in the Congress itself. I feel sure that it would be of the greatest value to show the Exhibition at this particular time - also I think that we should be able to draw upon financial assistance which would not be available to us normally and we could probably cover the expenses quite easily, but I should be glad to know what these are likely to be. I shall very much look forward to hearing from you again if the scheme develops.

Yours sincerely,

*J. L. Martin*

J. L. MARTIN M.A. Ph.D. A.R.I.B.A. SADIE SPEIGHT M.A. A.R.I.B.A.

vol. 3 no. 1

U.S. GOVERNMENT PRINTING OFFICE  
WASHINGTON, D.C.

*N.A.S.A. JOURNAL*  
*CONGRESS 1939*  
*SPECIAL NUMBER*

**HULL**

Fig 22. Cover of the Hull Congress catalogue, [1939] [ 45 pages document ].

[p 72]

**SATURDAY, MARCH 4.**

11-30 p.m. Congress Centre.

A Symposium : Architecture, Science,  
Economics and Society.

*Chairman :*

Dr. J. L. Martin, M.A., A.R.I.B.A.,  
Head of the Hull School of Architec-  
ture.

*Speakers :*

Serge Chermayeff, F.R.I.B.A., the  
distinguished modern architect.

Professor J. D. Bernal, M.A., F.R.S.  
Holds the Chair of Physics at Birkbeck  
College, London. Author of "The  
Social Function of Science," etc.

Professor E. Roll, B.Com., Ph.D.  
Holds the Chair of Economics at the  
University College of Hull. Author of  
"A History of Economic Thought,"  
etc.

E. J. Carter, Esq., B.A., A.A.Dip.,  
A.R.I.B.A. Librarian of the Royal  
Institute of British Architects and  
Editor of the *R.I.B.A. Journal*.

1-15 p.m. Powolnys' Restaurant, King  
Edward Street.

Lunch.

2-45 p.m. Congress Centre.

General Meeting. Mr. Colin Penn,  
Chairman of the A.A.S.T.A., will speak  
on "A Constructive Policy for the  
Architectural Profession."

4-30 p.m. Congress Centre.

Tea.

8-0 p.m. Powolnys' Restaurant, King  
Edward Street.

Hot-Pot Supper. Kindly given by the  
Sheriff of Hull.

10

Fig 23. Cover of the Hull Congress catalogue, [1939] [ 45 pages document ].

[p 72]

NORTHERN ARCHITECTURAL STUDENTS ASSOCIATION CONGRESS, HULL 1939.

SYMPOSIUM, Architecture, Science, Economics and Society.

2. Professor Bernal, M.A., F.R.S.

What I am going to do in the few minutes available is to sketch in one of the aspects that Ghermayeff mentioned, <sup>namely</sup> ~~that is~~ the part that scientific research has to play in this general scheme of a programme for architecture. I do not mean the purely academic science of the laboratory. I mean science as a way of doing things, as a way of setting things out. <sup>This is a plan</sup> ~~That is~~, for the architect to go outside the tradition in architecture and to find out what <sup>has</sup> ~~he has~~ done in technics.

Possibly few things have been so traditional as architecture. Every architectural tradition is worked to

death. It is carried beyond its logical conclusion. <sup>so that new style, as not developed</sup> ~~When it is finished it is~~

~~from it but a fresh start has to be made usually by going back to some style~~ <sup>is still earlier</sup> ~~dropped for something different. Gothic~~

<sup>developed for churches</sup> ~~broke down in the town halls under the~~ <sup>for palaces and</sup> ~~but only long after its ability had passed~~ ~~attain which had existed for a long time.~~

Fig 24. Desmond Bernal's manuscript for his speech at the Hull Congress. [ six pages document] [p 73]

*Telephone Welbeck 5721-234*

*Telegrams Ribazo Wesdo London*

## ROYAL INSTITUTE OF BRITISH ARCHITECTS

*Incorporated by Royal Charters of William IV. Victoria. Edward VII & George V*

66 PORTLAND PLACE, LONDON W.1

### BOARD OF ARCHITECTURAL EDUCATION

BH/JB

12th March, 1946.

Prof. J.D. Bernal, M.A., F.R.S.,  
Birkbeck College,  
Fetter Lane,  
London E.C.4.

Dear Professor Bernal,

During the discussion after your paper on Wednesday, the 6th March, and subsequently at dinner you will remember that the question was raised about action on the First Report of the Architectural Science Board on "The Place of Science in Architecture and on the Second Report on "The Teaching of Construction".

These Reports were referred by the Board of Architectural Education to the Special Committee on Architectural Education whose Report is about to be published. I have made a note to send for your acceptance as soon as it is published a copy of the Report.

The Special Committee on Architectural Education have of course discussed these matters at some length in their Report and they are recommending that these two Reports shall be brought to the notice of the Recognised Schools of Architecture.

Yours sincerely,

  
Secretary to the Board.

Fig 25. RIBA's letter to Desmond Bernal [1946].

[p 75]

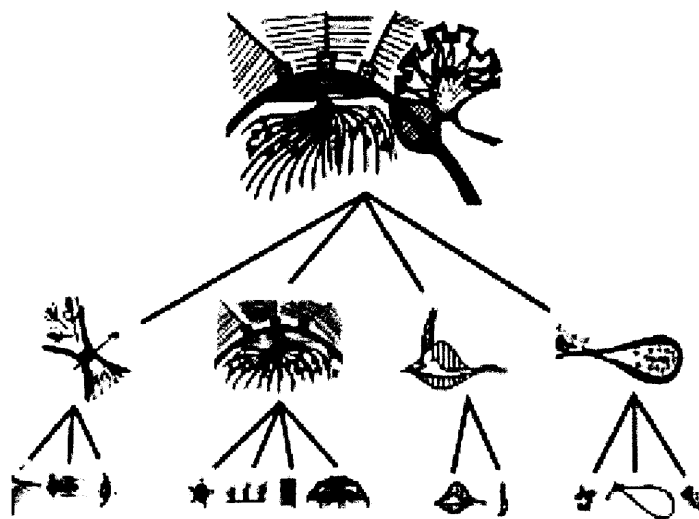


Fig 26. Diagram of a space-planning problem form " A Pattern Language," Christopher Alexander [1964]. [ p 31]

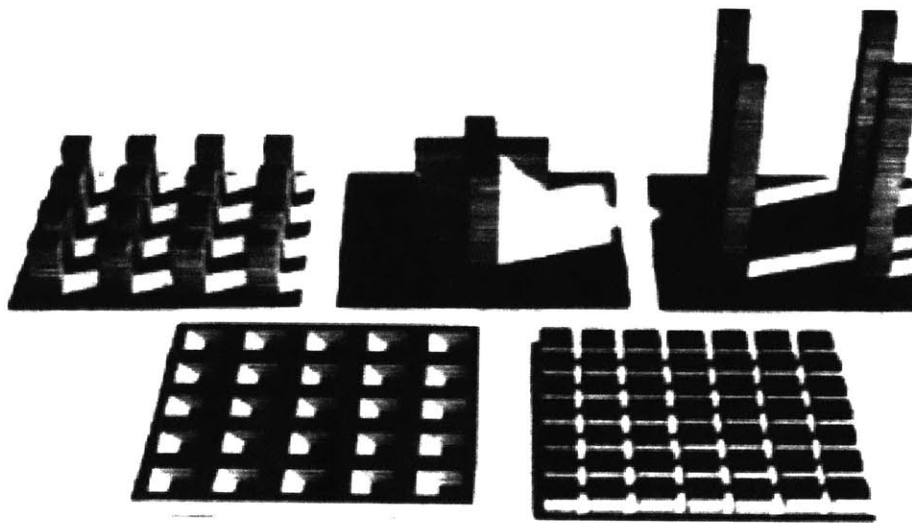


Fig 27. Model for the 'Whitehall Plan,' London, Leslie Martin and Lionel March [1966].

[p 79]

Plan form	Canonical polynomial	Simplified form	Binary code	Decimal code	Hexadecimal code
	0	0	0000	0	0
	$x_1^1 x_2^1$	$x_1 x_2$	0001	1	1
	$x_1^1 x_2^0$	$x_1 x_2'$	0010	2	2
	$x_1^1 x_2^0 + x_1^1 x_2^1$	$x_1$	0011	3	3
	$x_1^0 x_2^1$	$x_1' x_2$	0100	4	4
	$x_1^0 x_2^1 + x_1^1 x_2^1$	$x_2$	0101	5	5

0000 → 0  
 0001 → 1  
 0010 → 2  
 0011 → 3  
 0100 → 4  
 0101 → 5

0000 → 0  
 0001 → 1  
 0010 → 2  
 0011 → 3  
 0100 → 4  
 0101 → 5

0000 → 0  
 0001 → 1  
 0010 → 2  
 0011 → 3  
 0100 → 4  
 0101 → 5

Fig 28. 'Serial Art', Lionel March [1966].

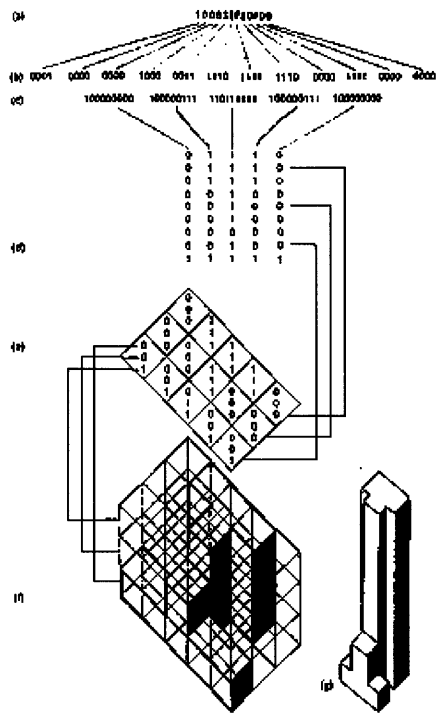


Fig 29. Binary code for "A Boolean Description of a Class of Built Forms," Lionel March [1976]. [p 80]

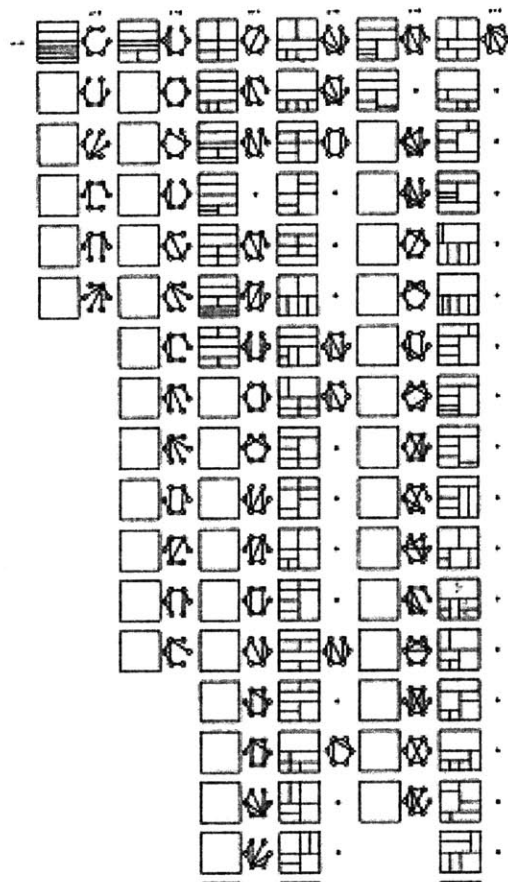


Fig 30. "Synthesis and Optimization of small rectangular floors," Philip Steadman [1976].

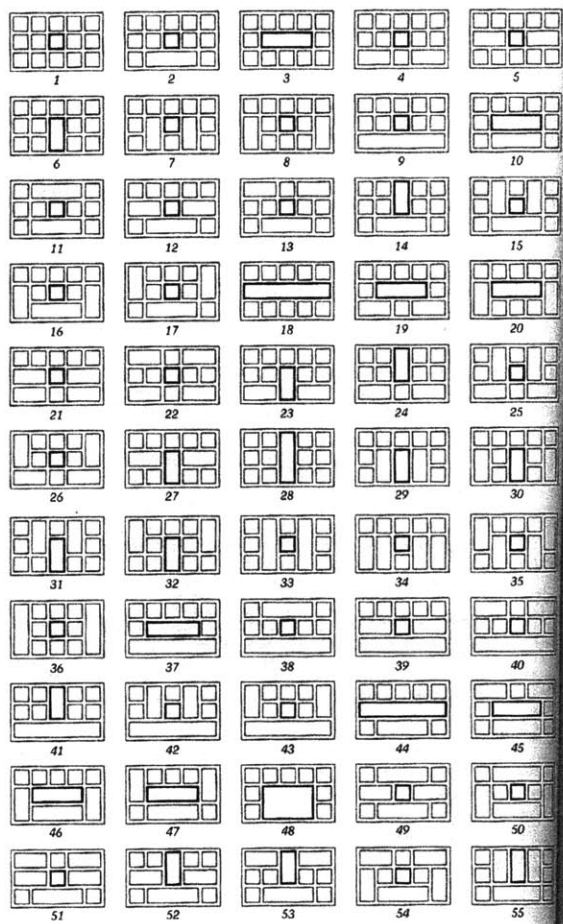


Fig 31. "Palladian Grammar," George Stiny and William Mitchell [1978].

[p 82]

COMPUTERS FOR ARCHITECTURAL DESIGN

When I dare to venture a few words on the potentialities of using computers for architectural design, I must emphasize that I am still a complete layman in this field and that my remarks are therefore of a mere speculative nature.

Is it at all imaginable that the phenomenal achievements of mechanical computers can be of influence to the creative process of architects and designers? Some people scorn violently the idea that lifeless machines could be of any advantage to inventive thinking. They feel that their intuitive power will be only disturbed by the forces of mechanization, that the willful and unique spark of a creative individual may be drowned in the attempt of mechanical fact finding.

I believe that by this attitude the baby is cast away with the wash.

In his remarkable book, "Mechanization Takes Command", Siegfried Giedion writes:

"Mechanization is an agent, like water, fire, light. It is blind and without direction of its own. It must be canalized. Like the powers of nature, mechanization depends on man's capacity to make use of it and to protect himself against its inherent perils. Because mechanization sprang entirely from the mind of man, it is the more dangerous to him. Being less easily controlled than natural forces, mechanization reacts on the senses and on the mind of its creator.

"To control mechanization demands an unprecedented superiority over the instruments of production. It requires that everything be subordinated to human needs."

We seem to be always wrong when we close the door too early to suggested new potentialities, being often misled by our natural inertia and aversion to the necessity of transforming our thoughts. Being not at home in the vast new field of computer systems, I want to be cautious. Still I believe, if we look at those machines as potential tools to shorten our working processes, they might help us to free our creative power.

Fig 32. Walter Gropius speech, "Computers for Architectural Design" [1964], [four pages document]. [p 91]

Box 1 ALEXANDER, CHRISTOPHER

A MUCH ASKED QUESTION ABOUT COMPUTERS AND DESIGN

(Handwritten initials)

Christopher Alexander

Since I use computers to solve both practical and theoretical problems in design, I have received a large number of enquiries from people who are interested in "The Application of Computers to Design." The most recent enquiry of this kind has come from the magazine Landscape, which is now kind enough to publish this reply:

In my opinion the question all these questioners ask, namely, "How can the computer be applied to architectural design?" is misguided, dangerous, and foolish.

We do not spend time writing letters to one another and talking about the question, "How can the slide rule be applied to architectural design?" We do not wander about our houses, hammer and saw in hand, wondering where we can apply them. In short, adults use tools to solve problems that they cannot solve without help. Only a child, to whom the world of tools is more exciting than the world in which those tools can be applied, wanders about wondering how to make use of his tools.

This would, of course, not be worth saying if there were hundreds of significant problems which the computer could help us solve. But there are not.

A digital computer is, essentially, the same as a huge army of clerks, equipped with rule books, pencil and paper, all stupid and entirely without initiative, but able to follow exactly millions of precisely defined operations. There is nothing a computer can do which such an army of clerks could not do, if given time.

Since the IBM 7090 takes  $10^{-5}$  ( $\frac{1}{100,000}$ ) seconds to do an elementary operation that might take a clerk about 10 seconds, it works about a million times as fast as a single clerk. One hour's operation on the

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## **Bibliography**

- Agrest, D and Gandelsonas, M. [1973, September]. "Semiotics and Architecture: Ideological Consumption or Theoretical Work," *Oppositions* 1.
- Allan, J. [1992]. *Berthold Lubetkin. Architecture and the Tradition of Progress*. London: RIBA Publications.
- Alexander, C. [1964]. *Notes on the Synthesis of Form*. Cambridge: Harvard University Press.
- Alexander, C. [1966]. "A City is not a Tree." *Design*, 206.
- Alexander, C and Poyner, B. [1966, July]. "The Atoms of Environmental Structure," Center for Planning and Development Research, University of California, Berkeley. [draft report]
- Banham, R. [1960]. *Theory and Design in the First Machine Age*. Cambridge, Mass: The MIT Press.
- Batty, M. [1994]. "Urban models 25 years on," *Environment and Planning B*. [21].
- Benjamin, W. [1969]. *Illuminations*. New York: Schocken Books.
- Benjamin, W. [1999]. *The Arcades Project*. Cambridge, Mass: Belknap Press.
- Bentley, P. [2002]. *Creative Evolutionary Systems*. San Francisco, CA: Morgan Kaufmann, San Diego, CA: Academic Press.
- Bernal, J. [1929]. *The World, the Flesh and the Devil*. London: Indiana University Press.
- Bernal, J. [1937, June]. "Architecture and Science," *RIBA Journal*, 44[16].
- Bernal, J. [1938, January-June]. "A Policy for Scientific Research for Britain," *The Nineteenth Century*, CXXIII.
- Bernal, J. [1939]. *The Social Function of Science*. London: G. Routledge & Sons Ltd.
- Bernal, J. [1941, June]. "Note on Research Organization in the Building Industry," British Architectural Library. SaG/99/2 papers.
- Bernal, J. [1946, March]. "Science in Architecture," *RIBA Journal*.
- Bernal, J. [1946, March 14]. "The Organization of Building Science Research," *The Architect's Journal*.
- Bernal, J. [1946a, December]. "Is Town Planning a Science?," *The Builder* .
- Bernal, J. [1949]. *The Freedom of Necessity*. London: Routledge & Kegan Paul .
- Bernal, J. [1969]. *Science in History*. Middlesex: Penguin Books. [1<sup>st</sup> edition 1954].

- Broadbent, J. [1973]. *Design in Architecture. Architecture and the Human Sciences*. New York: John Wiley & Sons.
- Bullock, N, Dickens, P and Steadman, P. [1968]. "A Theoretical Basis for University Planning," *LUBFS*, 1.
- Bush, V. [1945, July]. "As We May Think." *The Atlantic Monthly*. 176, [1].
- Cagan, J and Mitchell, W. [1993]. "Optimally directed shape generation by shape annealing," *Environment and Planning B*, [20].
- Caldas, L and Rocha, J. [2001]. "A Generative Design System Applied to Siza's School of Architecture at Oporto," in J.S. Gero, S. Chase and M Rosenman [Eds], *Proceedings of CAADRIA'01*, Key Center of design Computing and Cognition, University of Sydney, Sydney, 253-64.
- Caldas, L and Rocha, J. [2001a]. "An Evolutionary Model for Sustainable Design," *Proceedings of PLEA*. Florianopolis, November.
- Caldas, L. [2002]. "Evolving Three Dimensional Architectural Form," in JS Gero, [Eds], *Artificial Intelligence in Design' 02*, Key Center of Design Computing and Cognition, University of Sydney, Sydney. Kluwer Academic Publishers, 351-70.
- Caldas, L; Norford, L and Rocha, J. [2003]. "An Evolutionary model for sustainable design," *Management of Environmental Quality: An International Journal*, 14 [3], 383-97.
- Carey, H. [1984]. *Mansfield Forbes and his Cambridge*. Cambridge: Cambridge University Press.
- Carnap, R. [1937]. *The Logical Syntax of Language*. London: Routledge & K. Paul Ltd.
- Checkland, S. [2000]. *Ben Nicholson. The Vicious Circles of his life and art*. London: John Murray.
- Chermayeff, S. [1932, 14 September]. "Design in Industry. Design in Decoration and Furniture". Paper presented to the Design & Industries Association, The Victoria & Albert Museum, The Cambridge School of Architecture, The polytechnic School of Architecture. Columbia University. Avery Archive. Serge Chermayeff papers.
- Chermayeff, S. [1939]. *Plan for A.R.P. A Practical Policy for Air-Raid Precautions*. London: Frederick Muller, Ltd.
- Chermayeff, S and Alexander, C. [1963]. *Community and Privacy. Toward a new architecture of humanism*. Garden City, N.Y., Doubleday.
- Chomsky, N. [1957]. *Syntactic Structures*. 's-Gravenhage, Mouton.
- Chorley, R. [1967]. *Models in Geography*. [Richard Chorley and Peter Haggett, Eds]. London: Methuen.

- Cooke, C. [1995]. *Russian avant-garde theories of art, architecture and the city*. London: Academy Editions.
- Dannatt, T. [1959]. *Modern architecture in Britain: selected examples of recent building*. London: Batsford.
- Deleuze, G. [1993]. *The Fold. Leibniz and the Baroque*. University of Minnesota Press.
- Deleuze, G and Guattari, F. [2002]. *A Thousand Plateaus. Capitalism & Schizophrenia*. London: Continuum [1<sup>st</sup> edition 1980].
- Dreyfus, H. [1997]. *What Computers still can't do. A critique of Artificial Reason*. Cambridge, Mass: The MIT Press.
- Duarte, J and Simondetti, A. [1997]. "Basic grammars and rapid prototyping," *Proceedings of the 4th Workshop of the European Group for Structural Engineering Applications of Artificial Intelligence*, Lahti, Finland.
- Eagleton, T. [1990]. *The Significance of Theory*. Blackwell.
- Eastman, C. M. [1968]. "Explorations in the Cognitive Processes of Design," *Advanced Research Projects Agency Report*, Department of Computer Science. Carnegie Mellon University, Pittsburgh, Pennsylvania. AD 671188.
- Eastman, C. M. [1969, May]. "Cognitive Processes and Ill-Defined Problems: A Case Study from Design," *Proceedings Joint International Conference on Artificial Intelligence*, D. Walker and L. Norton [eds.], Washington.
- Eastman, C. M. [1969, June]. "Problem Solving Strategies in design," *EDRA I: Proceedings of the Environmental Design Research Association Conference*, H. Sanoff and S. Cohn [eds.], Chapel Hill, North Carolina. Published by the school of Design, North Carolina State University, [1970].
- Eastman, C. M. [1971, Sept.5-8]. "Heuristic Algorithms for Automated Apace Planning," *Second International Joint Conference in Artificial Intelligence*, Imperial College, London.
- Echenique, M. [1968]. *Models: a Discussion*. Working Paper N°. 6. Cambridge University School of Architecture.
- Eisenman, P. [1971, November-December]. "Notes on Conceptual Architecture: Towards a Definition," *Casabella*, n.359-360.
- Flemming, U. [1990]. "Syntactic Structures in Architecture," in M. McCullough, W. J. Mitchell, and P. Purcell, eds., *The Electronic Design Studio*. The MIT Press, Cambridge.
- Flemming, U. [1994]. "Get with the program: common fallacies in critiques of computer- aided architectural design," *Environment and Planning B*..

- Foucault, M. [1970]. *The order of Things: An Archaeology of the Human Sciences*. New York: Vintage Books.
- Foucault, M. [1972]. *The Archaeology of Knowledge*. New York: Pantheon Books.
- Frampton, K. [1974, May]. "Apropos Ulm," *Oppositions*, 3.
- Frazer, J. [1995]. *An Evolutionary Architecture*. London: Architectural Association Press.
- Galison, P and Thompson, E. [eds] [2000]. *The Architecture of Science*. Cambridge, Massachusetts. London: The MIT Press.
- Gandelonas, M. [1979]. "From Structure to Subject: the Formation of an Architectural Language," *Oppositions*.
- Gardiner, M. [1982]. *Barbara Hepworth. A memoir*. London: Lund Humphries publishers.
- Gardiner, M. [1988]. *A Scatter of Memories*. London: Free Association Books.
- Gero, J. [2001]. "The emergence of the representation of style in design," *Environment and Planning B*, 28.
- Giedion, S. [1948]. *Mechanization Takes Command*. New York: Oxford Univ. Press.
- Gips, J. [1975]. *Shape Grammars and their uses*. Basel: Birkhauser.
- Gips, J. [1979]. Artificial Intelligence. *Environment and Planning B* [6].
- Goméz, P. [1983]. *Architecture and the Crisis of Modern Science*. Cambridge. Mass: The MIT Press.
- Hawkes, D. [1976]. "Garden Cities and New Methods of Construction. Raymond Unwin's influence on English housing practice" In, Philip Steadman & Janet Owers [Eds.], *Transactions of the Martin Centre for Architectural & Urban Studies* [Vol 1. pp. 275-296]. Cambridge: University of Cambridge.
- Hawkes, D. [1984]. "The Cambridge School. Tradition, Research, Practice," *Architectural Review*.
- Hawkes, D. [2001]. The Shaping of architectural research," *arq*, 5[3]. Cambridge: Cambridge University press.
- Hays, M. [1995]. *Modernism and the posthumanist subject. The Architecture of Hannes Meyer and Ludwig Hilberseimer*. Cambridge, Mass: The MIT Press. [1<sup>st</sup> edition 1992].
- Hays, M. [1998]. *Architecture Theory since 1968*. [edited by K. M. Hays]. Cambridge, Mass: The MIT Press.
- Hays, M. [2001]. "Reflections on the State of Theory," *A+U*. [396].

- Hammer, M and Lodder, C. [2000]. *Constructing modernity: the art & career of Naum Gabo*. New Haven, CT: Yale University Press.
- Hepworth, B. [1970]. *A Pictorial Autobiography*. New York: Praeger.
- Hesse, M. [1963]. *Models and analogies in science*. London, New York: Sheed and Ward.
- Hitchcock, H, R. [1937]. *Modern architecture in England*. New York, The Museum of modern art.
- Holland, J. [1962]. "Outline for a logical theory of adaptive systems," *J. ACM*, 3.
- Holland, J. [1975]. *Adaptation in Natural and Artificial Systems*. Ann Arbor: University of Michigan Press.
- Holland, J. [1995]. *Hidden Order: How Adaptation Builds Complexity*. Addison-Wesley Publishing Company.
- Hofstadter, D. [1999]. *Godel, Escher, Bach. an Eternal Golden Braid*. Basic Books, Inc. [1<sup>st</sup> edition 1979].
- Klee, P. [1964]. *The Diaries of Paul Klee, 1898-1918*. Berkeley: University of California Press.
- Knight, T. [1994]. *Transformations in design: a formal approach to stylistic change and innovation in the visual arts*. Cambridge; New York: Cambridge University Press.
- Knight, T and Stiny, G. [2001]. "Classical and non-classical computation," *arq*, [5], 4. Cambridge: Cambridge University press.
- Kruft, H. [1994]. *A History of Architectural Theory. From Vitruvius to the Present*.
- Kuhn, T. [1996]. *The Structure of Scientific Revolutions*. Chicago: The University of Chicago Press. [1<sup>st</sup> edition 1962]
- Krishnamurti, R. [1982]. "SGI: a shape grammar interpreter," Research report, Center for Configurational Studies, The Open University.
- Krishnamurti, R and Earl, C.F. [1992]. "Shape recognition in three dimensions," *Environment and Planning B*, 18, 585-603.
- Leach, N. [1999]. *The Anaesthetics of Architecture*. Cambridge, Mass: The MIT Press.
- Leach, N. [1997]. *Rethinking architecture: a reader in cultural theory*. [edited by Neil Leach]. London; New York: Routledge.
- Lindinger, H. [1991]. *Ulm design: the morality of objects. Hochschule für Gestaltung Ulm, 1953-1958*. Cambridge, Mass: MIT Press.

- Lowry, I. S. [1964]. "A Model of Metropolis," [Rand Corporation, Santa Monica, CA].
- Lubetkin, B. [1932, May]. "Architectural Thought since the Revolution," *The Architectural Review*.
- MacCarthy, F. [1972]. *A History of British Design 1830-1970*. London: George Allen & Unwin Ltd.
- Maldonado, T. [1964]. "Scienza e progettazione." *Avanguardia e razionalità. Articoli, saggi, pamphlets 1946-1974*. Torino: Giulio Einaudi.
- Marcial, E. [1968]. "Models: a Discussion," Working Paper N°. 6. Cambridge University School of Architecture.
- March, L. [1966, February]. "Serial Art," *Architectural Design*.
- March, L. [1971]. "Circle," *Cambridge Review*.
- March, L. [1972, March]. "Modern movement to Vitruvius: themes of education and research," *RIBA Journal* 3.
- March, L. [1975]. "Models modes and mores," *LUBFS Conference Proceedings N°. 3*. [Richard Baxter, Marcial Echenique and Janet Owers, eds]. The Construction Press Ltd.
- March, L. [1976]. "A Boolean Description of a class of built forms," *The Architecture of Form*. Cambridge University Press.
- March, L. [1998]. *Architectonics of humanism : essays on number in architecture*. New York: Academy Editions.
- March, L. and Steadman, P. [eds]. [1971]. *The Geometry of environment. An introduction to spatial organization*. London: Methuen & Co ltd.
- March, L, Echenique, M and Dickens, P. [1971, May]. "Models of Environment. Polemic for a structural revolution," *Architectural Design* Vol XLI.
- Martin, L and Gabo, N. [1937]. *Circle. The International Survey of Constructive Art*. London: Faber and Faber.
- March, L. [1981]. "Theme issue: design and language," *Environment and Planning B*, 8.
- Martin, L. [1958, June]. "Conference on Architectural Education," *RIBA Journal*, 65, [8].
- Martin, L. [1965]. Whitehall: a plan for the national and government Centre /Leslie Martin. Accompanied by a Report on traffic / Colin Buchanan. London : H.M. Stationery Office.
- Martin, L. [1967, May]. "Architect's approach to Architecture," *RIBA Journal*.

- Martin, L. [1978, July]. "Notes on a Developing Architecture," *The Architectural Review*.
- Martin, L. [1982]. *Circle. Constructive art in Britain 1934-40*. Kettle's Yard Gallery [Jeremy Lewison, editor].
- Martin, L and Speight, S. [1939]. *Flat Book*.
- Marx, K. [1849]. "Wage-Labour and Capital." New York: International Publishers.
- McGrath, R. [1934]. *Twentieth Century Houses*. London: Faber and Faber.
- Mitchell, W. [1973]. "Vitruvius Computatus," *LUBFS Conference Proceedings*. N°.2 [Hawkes, D. eds ].
- Mitchell, W. [1974]. "Techniques of automated design in architecture: a survey and evaluation." University of California, School of Architecture report. Los Angeles, California.
- Mitchell, W. [1977]. *Computer Aided Architectural Design*. New York: Van Nostrand Reinhold.
- Mitchell, W. [1990]. *The Logic of Architecture. Design, Computation and Cognition*. Cambridge: The MIT Press.
- Mitchell, W., Steadman, P and Liggett, R. [1976]. "Synthesis and optimisation of small rectangular floor plans," *Environment and Planning B*, 3.
- Napper, J. [1975, November/December]. "The long Week-End," *RIBA Journal*.
- Negroponte, N. [1970]. *The Architecture Machine: toward a more human environment*. Cambridge, Mass: M.I.T. Press.
- Negroponte, N. [1970]. "Environmental Humanism Through Robots," *EDRA I: Proceedings of the Environmental Design Research Association Conference*, H. Sanoff and S. Cohn [eds.], Chapel Hill, North Carolina. Published by the school of Design, North Carolina State University, [1970].
- Nesbitt, K. [1996]. *Theorizing a new agenda for architecture: an anthology of architectural theory 1965-1995*.
- Nyce, J.M and Kahn, P [editors]. [1991]. *From Memex to Hypertext: Vannevar Bush and the Mind's Machine*. San Diego: Academic Press, Inc.
- O'Donovan, D. [?]. *God's Architect. A Life of Raymond McGrath*. Kilbride Books.
- Ockam, J. [1985] [ed]. *Architecture Criticism Ideology*. Princeton: Princeton Architectural Press
- Ockam, J. [1988]. "Resurrecting the Avant-Garde: The History and Program of Oppositions," *Architecturereproduction*. [Beatriz Colomina, eds]. Princeton Architectural Press.

- Ockam, J. [2001]. "The Pragmatism/Architecture: The idea of the Workshop Project," *The Pragmatist Imagination*. Princeton Architectural Press.
- Ockman, J. [1993]. "Architecture Culture 1943-1968: A Documentary Anthology." New York. Rizzoli.
- Ockman, J. [1995]. "Venice and New York," *Casabella*. 619-620.
- O'Reilly, U.M, Ross, I, Testa P [2000]. "Emergent Design: Artificial Life for Architecture Design," *Artificial Life 7*.
- O'Reilly, U.M; Kangas, M and Testa, P. [2000]. "MoSS: Morphogenetic Structure. A Nature Inspired Tool." MIT Paper.
- Peto, J., Loveday, D. [eds,] [1999]. *Modern Britain: 1929-1939*. London, Design Museum.
- Picon, A. [Ed.] [2003]. *Architecture and the sciences: exchanging metaphors*. New York: Princeton Architectural Press.
- Plunz, R. [1982]. *Design and the public good: selected writings 1930-1980. by Serge Chermayeff*. [edited by Richard Plunz]. Cambridge, Mass; London: MIT Press.
- Powers, A. [2001]. *Serge Chermayeff: Designer, Architect, Teacher*. London, RIBA Publications.
- Pritchard, J. [1972]. "Must we make the same mistake twice?," *Year Book of the Design and Industrial Association*.
- Pritchard, J. [1984]. *View from a Long Chair. The Memoirs of Jack Pritchard*. London, Boston: Routledge & K. Paul.
- Read, H. [1934]. *Art and Industry. The Principles of Industrial Design*. London, Faber & Faber.
- Read, H. [1965]. Marlborough Fine Art Ltd. *Art in Britain, 1930-40, centred around Axis, Circle and Unit one*. [Catalogue of an exhibition], March-April 1965, Marlborough Fine Art, ltd., and Marlborough New London Gallery.
- Reiss, L. [1933, January 25]. "Housing-the Last Decade and the Next," *The Listener*.
- Reading, M and Coe, P. [1992]. *Lubetkin & Tecton. An Architectural Study*. London: Triangle Architectural Publishing.
- Rebuilding Britain [1943]. Catalogue of the Exhibition at the National Gallery, London
- Reuleaux, F. [1963]. *The Kinematics of Machinery; outlines of a Theory of Machines*. New York: Dover Publications. [1st edition 1875].

- Rosenbaum, S. P. [1975]. *The Bloomsbury Group: a collection of memoirs, commentary and criticism*. Toronto, Buffalo: University of Toronto Press.
- Saussure, F. [1959]. *Course in General Linguistics*. New York: Philosophical Library.
- Scheffauer, H. [1924, December]. "The Work of Walter Gropius," *The Architectural Review*. Vol. LVI.
- Schultz, H. [1938]. *The Theory and Measurement of Demand*. Chicago: The University of Chicago Press.
- Schulz, C.N. [1997]. *Intentions in Architecture*. Cambridge, Mass: The MIT Press. [1<sup>st</sup> edition 1965]
- Shea, K and Cagan, J. [1998]. "Generating Structural Essays from Languages of Discrete Structures," in J. S Gero and F. Sudweeks [eds], *Artificial Intelligence in Design '98*, 365-384. Kluwer Academic Publishers.
- Simon, H. [1969a]. *The Sciences of the Artificial*. Cambridge: The MIT Press.
- Simon, H. [1971]. "Style in Design," *Proceedings of the 2<sup>nd</sup> Annual Conference of the Environmental Design Research Association*. Pittsburgh, PA: Carnegie Mellon University.
- Simon, H. [1996]. *Models of my Life*. Cambridge, Massachusetts, London: MIT Press.
- Simon, H. [1996a]. *Models of my Life*. Cambridge, Massachusetts: MIT Press.
- Skinner, Q. [2000]. *The Return of grand Theory in the Human Sciences*. Cambridge: University Press. [1<sup>st</sup> edition 1985].
- Snow, C.P. [1998]. *The Two Cultures*. Cambridge: Cambridge University Press. [1<sup>st</sup> edition 1959].
- Steadman, P. [1970]. "The Automatic Generation of Minimum-Standard House Plans." 'Land Use and Built Forms Studies'. Working paper 23.
- Steadman, P. [1976]. "Graph-theoretic representation of architectural arrangement." *The Architecture of Form*. [Martin, L and March, L; eds].
- Steadman, P. [1979]. *The evolution of designs. biological analogy in architecture and the applied arts*. Cambridge, New York: Cambridge University Press.
- Steadman, P. [1983]. *Architectural Morphology. An introduction to the geometry of building plans*. London: Pion Ltd.
- Steiner, G. [2001]. *Grammars of Creation*. London: Faber and Faber.
- Stewart, R. [1987]. *Design and British Industry*. London: John Murray [Publishers] Ltd.

- Stiny, G. [1976]. "Two exercises in formal composition," *Environment and Planning B*, 3.
- Stiny, G. [1986]. "Computational foundations of architectural design," *Environment and Planning B*, 13.
- Stiny, G. [1991]. "The Algebras of Design," *Research in Engineering Design*. New York: Springer-Verlag.
- Stiny, G and Gips [1972]. "Shape Grammars and the Generative Specification of Painting and Sculpture," *Information Processing 71*. Ed.C. V Freiman. Amsterdam: North Holland.
- Stiny, G and Mitchell, W. [1978]. "The Palladian grammar." *Environment and Planning B*, 5.
- Stiny, G and Gips, J. [1978]. *Algorithmic Aesthetics*. Berkeley: University of California Press.
- Stokes, A. [1947]. *Inside Out. An Essay in the Psychology and Aesthetic Appeal of Space*. London: Faber and Faber.
- Strauss, L. C. [1958]. *Structural Anthropology*. publ. Allen Lane, The Penguin Press.
- Strauss, L. C. [1995]. *Myth and the Meaning. Cracking the Code of Culture*. University of Toronto Press.
- Swan, B and Aprahamian, F. [eds] [1999]. *J.D. Bernal. A Life in Science and Politics*. London: Verso.
- Tafuri, M. [1970]. *Teorie e Storia dell'architettura*. Bari: Laterza Editirici.
- Tafuri, M. [1973]. *Progetto e Utopia. Architettura e Sviluppo Capitalistico*. Bari: Laterza Editirici.
- Testa, P; O'Reilly, U.N; Weiser, D and Ross, I. [2001]. "Emergent Design: a crosscutting research program and design curriculum integrating architecture and artificial intelligence," *Environment and Planning B*, 28, 481-98.
- Thompson, D.A. [2000]. *On Growth and Form*. Cambridge: Cambridge University Press.
- Waddington, C. H. [1969]. *Behind Appearance, a study of the relations between the natural sciences in this century*. Cambridge, Mass: MIT Press.
- Werskey, G. [1978]. *The Visible College*. London: Penguin Books.
- Wigley, M. [1996]. *The Architecture of Deconstruction. Derrida's Haunt*. Cambridge, Mass: The MIT Press. [1<sup>st</sup> edition 1993].
- Wind, E. [1963]. *Art and anarchy*. New York: Knopf, 52.
- Wittgenstein, L. [1997]. *Philosophical Investigations*. Oxford, Malden, Mass: Blackwell.

Wittkower, R. [1971]. *Architectural Principles in the Age of Humanism*. New York: W. W. Norton.

Zuckerman, S. [1978]. *From Apes to Warlords, 1904-46*. London: Hamilton.

## **Archives**

The Martin Centre Archive, The Martin Center, Cambridge, UK

John Desmond Bernal Archive. Cambridge Library, University of Cambridge, UK.

Serge Chermayeff Archive, Avery Archive, Columbia, University. New York, NY, USA

The British Architectural Library, RIBA, London, UK.

