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The Impact of Space Configuration on the Progress of Science

A Case Study of Research Laboratories

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بسم الله الرحمن الرحيم

وقل رب زدني علما

صدق الله العظيم

Contents

Acknowledgements v
Abstract vii
Problem Definition viii
Research Objectives ix
Research Methodology ix
Introduction x

Chapter One: The Research Laboratory 1-38

1.0 Introduction 1
1.1 The research laboratory: An architectural problem 1
1.2 Factors affecting the performance of researchers in a research laboratory 5
1.3 Origin and historical development 7
1.4 Space Ergonomics of the Research Laboratory 20
1.4.1 The Nuffield Study 21
1.5 Communication and Problem Solving 23
1.6 The Architecture: Generative or Conservative Building Models 31
1.6.1 Kinds of movement in a research laboratory building 32
1.7 Summary 37

Chapter Two: The Space Syntax Methodology and Analytical Tools 39-53

2.0 Introduction 39
2.1 Definition of Space Syntax 39
2.1.1 The Methodology 40
2.1.2 The Spatial Logic of Movement 41
2.2 Analytical Tools 42
2.2.1 Axial analysis 42
2.2.2 Boundary analysis 46
2.2.3 Justified Permeability Graphs 48
2.3 Summary 53

Chapter Three: Architectural Review of Selected Research Laboratories 54-168

3.0 Introduction 54
List of Selected Research Laboratory Buildings 54
3.1 Architectural Review of Selected Research Laboratories 56
3.1.1 The National Research Centre, NRC, Dokki, Egypt. 56

Contents

3.1.2 The Housing and Building Research Centre, **HBRC**, Dokki, Egypt. 63
3.1.3 The Gamma Irradiation Facility, **GIF**, Atomic Energy Authority, Nasr City, Egypt. 71
3.1.4 The National Centre for Nuclear Safety and Radiation Control, **NCNSRC**, Atomic Energy Authority, Nasr City, Egypt. 79
3.1.5 The Institute for Genetic Engineering, **IGER**, Mubarak City for Scientific Research, New Borg El-Arab, Egypt. 82
3.1.6 Schlumberger Cambridge Research Centre, **SCRC**, Cambridge, UK. 94
3.1.7 Camelia Botnar Laboratories, **CBL**, Great Ormond Street Hospital, London, UK. 101
3.1.8 Institute of Medical Sciences, **IMS**, University of Aberdeen, Scotland, UK. 105
3.1.9 Biological Sciences Complex, **BSC**, University of Georgia, Athens, Georgia, USA. 110
3.1.10 Skirball Institute of Biomolecular Medicine, **SIBM**, New York University, New York City, USA. 113
3.1.11 Rhone-Poulenc Rorer US headquarters, **RPRRC**, Collegeville, Pennsylvania, USA, 1994. 118
3.1.12 Kazusa DNA Research Institute, **KDNARI**, Kisarazu City, Chiba, Japan. 124
3.1.13 Sandoz Tsukuba Research Centre, **STRC**, Tsukuba City, Ibaraki, Japan. 134
3.1.14 Bayer Yakuhin Research Centre, **BYRC**, Kizu Town, Kyoto, Japan. 142
3.2 Comparative Analyses 152
Table 3.2a of Advantages and Disadvantages of the Egyptian Sample 153
Table 3.2b of Advantages and Disadvantages of the British Sample 154
Table 3.2c of Advantages and Disadvantages of the American Sample 155
Table 3.2d of Advantages and Disadvantages of the Japanese Sample 156
3.3 Discussion 157
3.3.1 Summary of the Egyptian Sample 157
3.3.2 Summary of the British Sample 159
3.3.3 Summary of the American Sample 160
3.3.4 Summary of the Japanese Sample 161
3.4 The Scoring Criteria 162
Table 3.4.1 Comparison of the Contents of Research Laboratories 165
Table 3.4.2 Summary of table 3.2 in percentages 166
3.5 Summary 167

Contents

Chapter Four: Spatial Analyses of Research Laboratories 169-363

4.0 Introduction 169
4.1 Sites Analyses 170
4.2 The Spatial Analyses of Research Laboratories 180
4.2.1 The National Research Centre, **NRC**, Dokki, Giza, Egypt. 181
4.2.2 The Housing and Building Research Centre, **HBRC**, Giza, Egypt. 194
4.2.3 The Gamma Irradiation Facility, **GIF**, Atomic Energy Authority, Nasr City, Egypt. 205
4.2.4 The National Centre for Safety and Radiation Control, **NCNSRC**, Atomic Energy Authority, Nasr City, Egypt. 217
4.2.5 The Institute for Genetic Engineering, **IGER**, Mubarak City for Scientific Research, New Borg ElArab, Egypt. 226
4.2.6 Schlumberger Cambridge Research Centre, **SCRC**, Cambridge, UK. 237
4.2.7 Camelia Botnar Laboratories, **CBL**, Great Ormond Street Hospital, London, UK. 248
4.2.8 Institute of Medical Sciences, **IMS**, University of Aberdeen, Scotland, UK. 256
4.2.9 Biological Sciences Complex, **BSC**, University of Georgia, Athens, Georgia, USA. 269
4.2.10 Skirball Institute, **SI**, New York University, New York City, USA. 279
4.2.11 Rhone-Poulenc Rorer US headquarters, **RPRRC**, Collegeville, Pennsylvania, USA. 290
4.2.12 Kazusa DNA Research Institute, **KDNARI**, Kisarazu City, Chiba, Japan. 304
4.2.13 Sandoz Tsukuba Research Centre, **STRC**, Tsukuba City, Ibaraki, Japan. 315
4.2.14 Bayer Yakuhin Research Centre, **BYRC**, Kizu Town, Kyoto, Japan. 324
4.3 Comparative Analyses 332
4.3.1 Analyses by numbers 333
4.3.2 Analyses by integration 335
4.4 Ranking of functions in research laboratories according to mean integration values 340
4.5 Justified Permeability Graphs 347
4.5.1 Summary of Justified Permeability Graphs 347
4.5.2 Analyses of Justified Permeability Graphs 349

Contents

4.6	Symmetry of Plans	353
4.7	Conclusions	360
4.8	Summary	365

Chapter Five: Summary, Conclusions and Recommendations 367-373

5.1	Summary	367
5.2	Conclusions	368
5.3	Recommendations	369

References 374-377
English Summary 378
Arabic Summary 380

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Research showed that consultation with colleagues from outside the research group but from within the organisation proved essential to successful problem solving.

This research argues that the layout of the architectural plan is instrumental in promoting or hindering social interaction among inhabitants of a research laboratory. It also argues that the presence or absence of meeting facilities like cafes, meeting rooms and break out spaces aid or hinder social interaction respectively. Managerial decisions also play a sensitive role in the process.

It is argued that symmetrical plans dramatically reduce communication among users of the floor plan and consequently hinder the process of interaction and thus have a negative effect on the progress of science in research laboratories.

Most previous research on research centres focused mainly on space ergonomics, technical problems like the supply of services like water and gas, finishings used in research laboratories, flexibility of design, design of program and some research focused on architectural form.

Research argues that consultation among colleagues working in the same organisation but not necessarily in the same research group is instrumental in the achievement of better qualities of problem solving.

What makes research better at a research centre rather than at home? There are two reasons for this: First, is using the equipment and facilities provided by research centre. Second, is the face to face interaction and consultations with fellow scientists and researchers, that can lead to problem solving and innovation.

The question to be asked is: How can the building of a research centre aid in achieving more interaction? Can it hinder interaction? What affects the rate of interaction? How can a building help people interact without having to knock on each others doors?

As an architect working at the NCNSRC research centre it has been my concern how the architect can, through the architectural plan promote communication or otherwise, among the inhabitants of a research centre.

Research Objectives

This research intends to do the following:

One, to evaluate an international sample of research laboratories for the presence of the facilities provided by each building and site and rank them accordingly.

Two, to spatially analyse research laboratory buildings, examine the results, compare them and then rank the buildings accordingly.

Three, make an evaluation as to whether the spaces were in the right spatial order of functions or not and rank the buildings accordingly.

Four, to rank the research laboratory buildings according to available facilities *and* spatial qualities.

In this way, the research intends to evaluate the spatial configuration of research laboratory buildings.

Research Methodology

In this research the analytical and the comparative analytical methodology of research have been used. The space syntax analytical tools which are descriptive and analytical have been extensively used. In chapter one, the the deduction method of research has been used in the literature review of research centres. In chapter three, the comparative and the comparative analysis method has been used in comparing the research centres. In chapter four, the spatial descriptive analytical method and comparative analytical method have been used for comparing spatial qualities of research centres.

This research is directed towards the understanding of how research laboratory buildings work for scientists and whether the buildings can promote communication among its users or otherwise, which consequently can influence the progress of research in the building.

Chapter one reviews the literature written about research laboratories. It outlines that random encounter can have an effect on problem solving and innovation in science.

Chapter two introduces the space syntax theory, techniques and analytical tools.

Chapter three architecturally reviews 14 research laboratories: five Egyptian research laboratories, three British research laboratories, three American research laboratories and three Japanese research laboratories. It points out the advantages and disadvantages of each of the 14 design. Finally it comparatively analyses the services offered by each research laboratory and ranks them according to the services they offer to their users.

Chapter four spatially analyses the 14 typical floors of the research laboratories axially and boundary wise. In this way it tries to pin down how the layout of the architectural plan generates movement and thus induces social interaction and consequently there is expected to be an interface of social & scientific knowledge exchange or conserves movement, social interaction and consequently knowledge and science. At the end of the chapter analytical spatial comparisons among the plans are established and conclusions are drawn. It is argued out that mirrored and repeated parts of the plan, which all architects often do, can have a worsening effect on integration, i.e. in other words there is a clear message to architects that by enlarging architectural plans by repeating a unit -which has been an architectural solution for a very long time- the spatial quality of integration (1/x RRA) is reduced a great deal which has a direct effect on communication and consequently the flow of science and information. Justified permeability graphs are used to show the effect of integration on mean depth.

Chapter five draws discussions, conclusions and recommendations on different levels.

Chapter One

The Research Laboratory 1-38

1.0	Introduction	1
1.1	The research laboratory: An architectural problem	1
1.2	Factors affecting the performance of researchers in a research laboratory	5
1.3	Origin and historical development	7
1.4	Space Ergonomics of the Research Laboratory	20
1.4.1	The Nuffield Study	21
1.5	Communication and Problem Solving	23
1.6	The Architecture: Generative or Conservative Building Models	31
1.6.1	Kinds of movement in a research laboratory building	32
1.7	Summary	37

Introduction

The research laboratory is an important building type for the advancement of any nation. According to Braybrooke[1], it is a forum for the advancement of many areas of knowledge, the environment in which creative minds must function, the repository for enormously valuable equipment, and it represents significant national corporate and institutional investment in the future. Zewail[2] writes:

> *"What keeps American science on the forefront of new frontiers is in reality a handful of outstanding institutions – not every university in America had costly facilities and a distinguished faculty."*

Yet as important as it sounds, Braybrooke argues that the building type has maintained a low profile as a design problem and a vehicle for distinguished architecture. And Weeks[3] states clearly that research laboratory buildings "do not attract 'star' architects".

1.1 The Research Laboratory: An Architectural Problem

Why is the research laboratory considered as an unattractive building type for architects to design? The reasons are highlighted in the following factors:

---

[1] Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA. Preface, p. xi. 1986.

[2] Zewail, A., Voyage through Time, Walks of Life to the Nobel Prize, The AUC Press, 2002, p. 79.

[3] Weeks, J., A Design Approach, p. 4 in Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA. 1986.

First, as Gould[4] points out, the most important part of designing any building and in particular a complicated one like a research laboratory, is the programme. The programme can only be identified from a brief prepared by the client with or without the help of the architect. But since the client of a research laboratory is a large number of people, each with a different need, it can be understandable why the process of identifying the programme alone can give the architect a big headache.

Second, the space ergonomics of research laboratories. These are the physical characteristics of the laboratory environment, the metric space needed for each researcher, the height and depth of benches, and the rational lighting criteria for each specific task like performing an experiment, reading, writing, etc. Before the 1960s, this was a problem, but now a substantial amount of research has been invested on this factor.

Third, the technical solutions required to provide services like gas, water, fume-hoods, and other specific services, to all laboratories and the safety considerations that are necessary to these provisions. This factor also has been the focus of a lot of research and literature and some firms specialise in solving these technical problems which helps architects focus on architectural design.

Fourth, because of the nature of the research process, it means that scientists change what they do over time, which means that there could be a change in

[4] Gould, B. P., Facilities Programming, in Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA, 1986. P.19.

programme between the time the programme of the building was made and the time the building is completed. This can lead to frustration for both the client and the architect. Although in generating the programme questions about the future of the research and its needs can be asked, yet again because of the nature of the research process scientists cannot precisely foretell what they would need in the future, so this can be a problem. Thus the solution of flexibility becomes a necessity[5].Weeks has stressed the ephemerality of the client's program compared to the whole life of the building, while Haines[6] explained this problem of the program of research laboratories in a few words: "*Too often tomorrow's buildings are designed today to provide for yesterday's needs.*" For this reason Gould pointed out that research buildings should be designed for specific requirements but ones that have to be capable of expansion and of change.

Fifth, lately in the past twenty years, in many projects, architects have been requested to design buildings that promote social interaction between users.

The previous discussion concludes that before functional priorities get solved, architects cannot start to think about the form of the building. That is the explanation of the researcher of the reason, that research laboratories as building types are unlikely to become the dream buildings for architects. But specialisation solved this problem; there can be firms specialised in solving

[5] Lots of literature has mentioned the importance of flexibility, see Griffin, Brian, Laboratory Design Guide, Architectural Press, 1998 and Mayer, Leonard, *Design and planning of Research and Clinical Laboratory Facilities*, New York, John Wiley and Sons.
[6] Haines, C., Planning the Scientific Laboratory in *Buildings for Research*, F.W. Dodge Corporation, USA, 1958, p.4.

1.2.4 **Economical factors:** Budget for research and for updating equipments.

1.2.5 **Administrative factors:** Global research plan, the quality of leadership and the amount of working hours.

1.2.6 **Facilities:** The provision or otherwise of recreational facilities serving food and beverages, and meeting facilities for the use of senior and junior staff.

1.2.7 **Spatial aspect of the site plan:** Whether the site integrates buildings or segregates them and the position of the research laboratory to the whole site plan.

1.2.8 **Spatial aspects of the layout of the architectural plan:** Whether it integrates users or segregates them, being a generative or conservative building model, intelligibility: how users understand the building, transparency, the positions of cafes, photocopying rooms, coffee rooms, meeting rooms, toilets.

1.2.9 **Cultural aspects:** The impact of the culture of users of the building.

1.2.10 **Social aspects:** Communication and innovation, strong and weak social ties.

1.2.11 **Transpatial aspects:** Communication through the attendance of conferences & seminars, use of internet, electronic mail.

1.2.12 **Transportation**: To and from the site (buses, public transport).

This research is specifically going to address aspects from **1.2.6-1.2.10**.

1.3 Origin and Historical Development of Research Laboratories

The history of the laboratory as a specialised building type began, as Weeks[7] argues, with the alchemist's cell. When chemistry began to appear as a scientific discipline, rooms for experimental work began to be depicted in a more objective way. In drawings of the first scientific laboratories in universities in the early eighteenth century, the apparatus can be seen clearly. Several furnaces were grouped at the sides of the room, discharging into a common hood. Stout tables were provided to support the increasingly complex apparatus. In the famous drawing of Lavoisier's laboratory, shown in **figure 1.3.1**, the scientist is dictating notes on the progress of the experiment to his wife, seated at a writing table. This was the beginning of careful observation and exact recording.

[7] Weeks, J., A Design Approach, p. 4 in Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA. 1986.

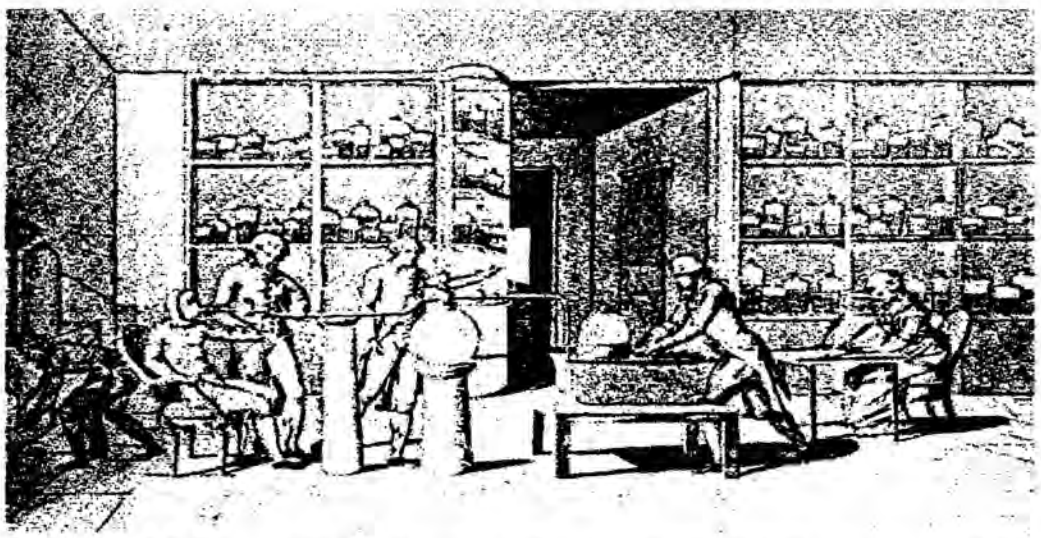

Figure 1.3.1 Lavoisier's laboratory, the scientist is dictating notes on the progress of the experiment to his wife, seated at a writing table
Source: Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA. 1986

Weeks reports that in the 1850's coal began to be used as a local heat source, as it proved hotter than candles and spirit lamps and more flexible and controllable than a furnace. Thus piped services to benches appeared. In newly built laboratories in the nineteenth century, sinks got built into benches with gas, water and drainage connected to them. Benches became massive with teak topped fixtures. By the 1950s the laboratory bench had become the base for often very elaborate arrays of apparatus using electricity, compressed air, steam, demineralised water and suction, all available from a services manifold. The laboratory was planned around the benches as they had become part of the building, totally immovable except by a construction crew.[8]

Soloman[9] argues that architectural historians classify the design of laboratories by generations, where the first generation is characterised by solving the technical problems of the laboratory unit by grouping the laboratories together and providing services to them through pipes fixed along the wall and hidden by panels for architectural beauty. A good example of this generation can be demonstrated through the Bell Laboratories, (see **figures 1.3.2-1.3.6**) built in Murray Hill, New Jersey, USA in the late 1930's, designed by Voorhees, Walker, Foley and Smith of New York. Soloman points out that it remained for decades the paradigm for laboratory design. The main building is an assembly of "T" and cross units, consisting of either one or two office wings, connected to twenty-eight modules of technical space. The research laboratories consisted of repetitive laboratory modules flanked by shared corridors. **Figure 1.3.3** is a typical floor plan where an auditorium can be seen on the right hand side of the site. Also there are two large dining areas on site. Notice in the detailed plan in **figure1.3.3** that research labs are grouped together away from the main corridor to achieve privacy and quietness. **Figures 1.3.4-1.3.6** show the technical details of solutions to provide flexibility in lab space. The layout of this architectural plan, characterised with long wings, symmetry and mirroring around an axis with

[8] Weeks, J., A Design Approach, p. 4 in Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA. 1986.
[9] From Soloman, Nancy, Laboratory Innovations, Architecture Magazine, March 1993, p. 123-127.

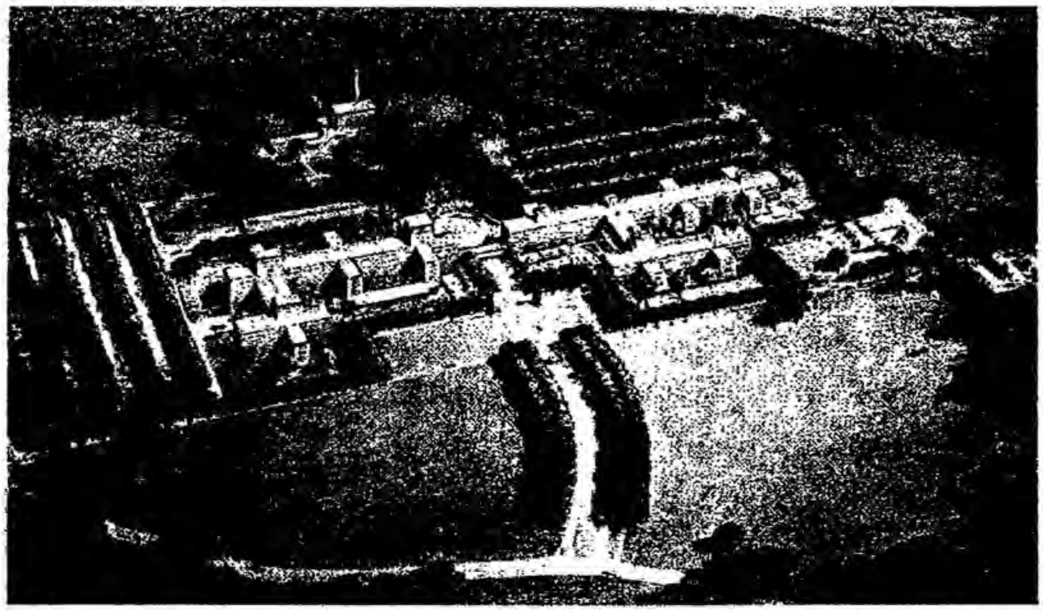

Figure 1.3.2 Aerial view of Bell Telephone Laboratories at Murray Hill, New Jersey

Source: *Laboratory Design*, Coleman, H. S., National Research Council, Report on Design, Construction and Equipment of Laboratories, Reinhold publishing Corporation, New York, 1951

services embedded in walls and floors dominated laboratory design till the late 1950s.

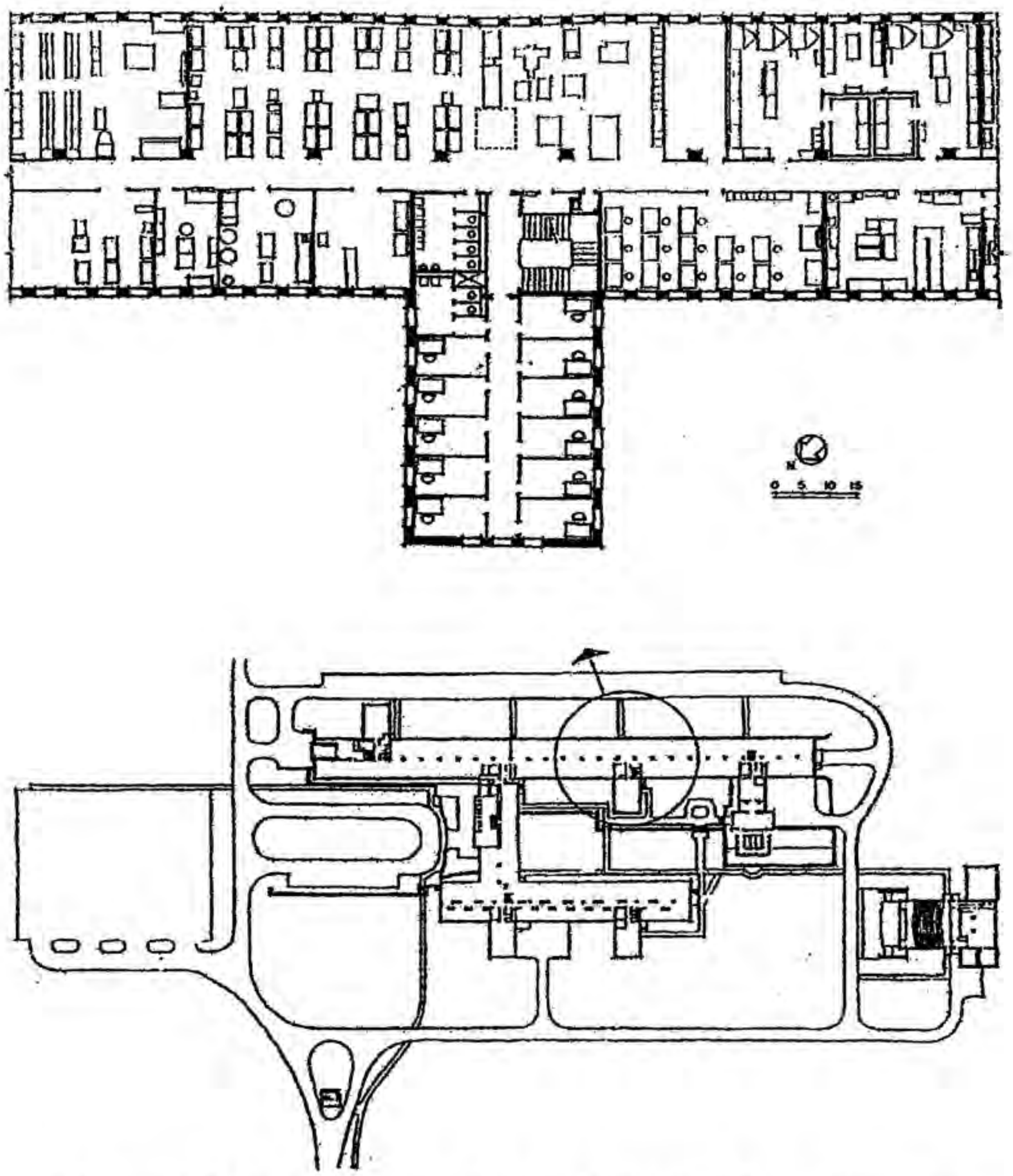

Figure 1.3.3 The whole plan of the main building of Bell Telephone Laboratories with detail of "T" unit shown above

Source: Coleman, H. S., *Laboratory Design, National Research Council, Report on Design, Construction and Equipment of Laboratories*, Reinhold Publishing Corporation, New York, 1951

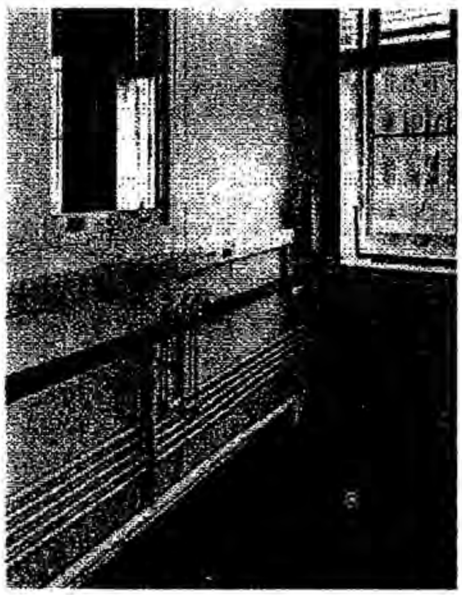

Figure 1.3.4 The innovation was in the provision of services through walls.

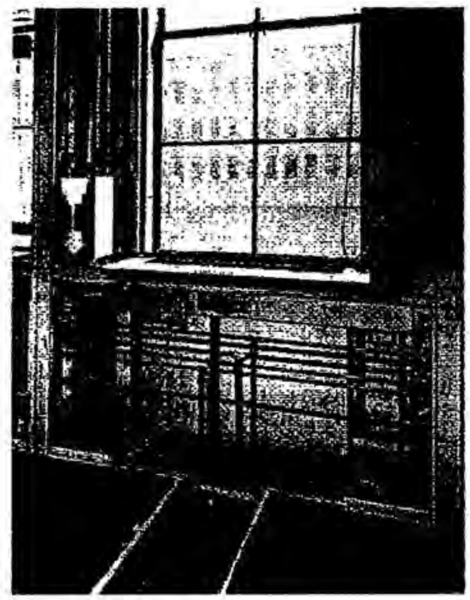

Figure 1.3.5 Services run through walls and floors.

Source: Coleman, H. S., *Laboratory Design, National Research Council, Report on Design, Construction and Equipment of Laboratories*, Reinhold Publishing Corporation, New York, 1951.

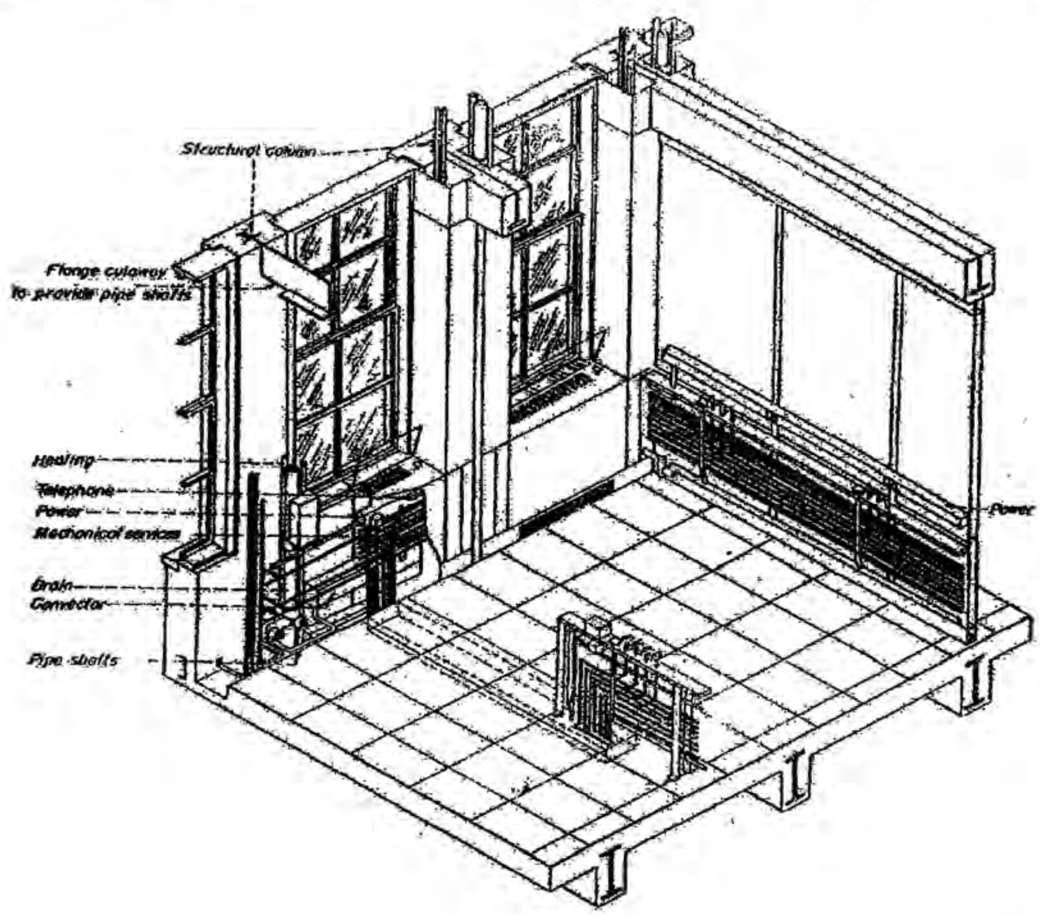

Figure 1.3.6 Isometric diagram of two laboratory modules showing the innovation in services running in lab walls and floors.
Source: Coleman, H. S., *Laboratory Design, National Research Council, Report on Design, Construction and Equipment of Laboratories*, Reinhold Publishing Corporation, New York, 1951

According to Solomon, architectural historians classified the Salk Institute for Biological Studies designed by Louis Kahn, as the second generation of lab design because of its revolutionary approach to solving the problem of flexibility of servicing through an 'interstitial space'. This is a floor above the laboratory floor, designated just for services which can be reached through the ceiling of the lab and thus high flexibility can be achieved. But the researcher points out that it was not because only the emergence of interstitial space. It was because of Kahn's realisation[10] that such a complicated building as the research laboratory, needed several specialisations in consultancies and that it is difficult for the architect to try and solve all problems involved, so he hired a lab consultant, Earls Walls, to be in charge of solving the technical problems of the design. According to Cohen[11], Walls was the one who came up with the idea of creating a 2.7m interstitial space on top of each of the three stories of the labs to house plumbing, air conditioning, heating, ventilation, gas lines and electrical wires. This idea facilitated the flexibility thus taking all the mess away from the plan and giving rise to the idea, new at the time, of the open laboratory, which changed the concept of lab design altogether and made relocation of lab benches and the updating of mechanical equipment possible. A system of trusses in the interstitial space holds up the ceiling in the lab below and supports the ceiling of the lab above. As a result, the labs had no hindering structure system, thus allowing users to configure and reconfigure lab space as they chose. The other feature

[10] After his failure in solving the plan of the Richards Medical Research Laboratories at the University of Pennsylvania, completed in 1962, he decided to hire a specialist to do the job. He had come up with an eye-catching design; 10-storey stacks of studios that he framed with even taller brick "service" towers. According to architectural historians it appeared to be an inspired innovation but actually it was a near disaster as the scientists who hadn't been accommodated in discussing the design became really hampered in their research. It was a nice form but it was not functional for scientific research. The exposed pipes collected dust in the interiors, there was shortage of wall space for refrigerators and Kahn's use of windows was extensive. After several trials from behalf of the scientists to reduce the glare, Kahn agreed to hang shades over the windows.

[11] Cohen, Jon, Designer Labs: Architecture Discovers Science, Science 2000, Vol. 287, Number 5451, Issue of 14/1/2000 in News Focus, p.212.

was that big labs allowed interdepartmental communication as more than one department used a lab. Users refer to it as being one big lab where students and post doctoral mingle.[12] Kahn also separated the research offices from the laboratories and made the garden their view. The garden also became a big break out space where scientists could meet, talk and socialise. **Figure 1.3.7** represents the plan of the Salk Institute,

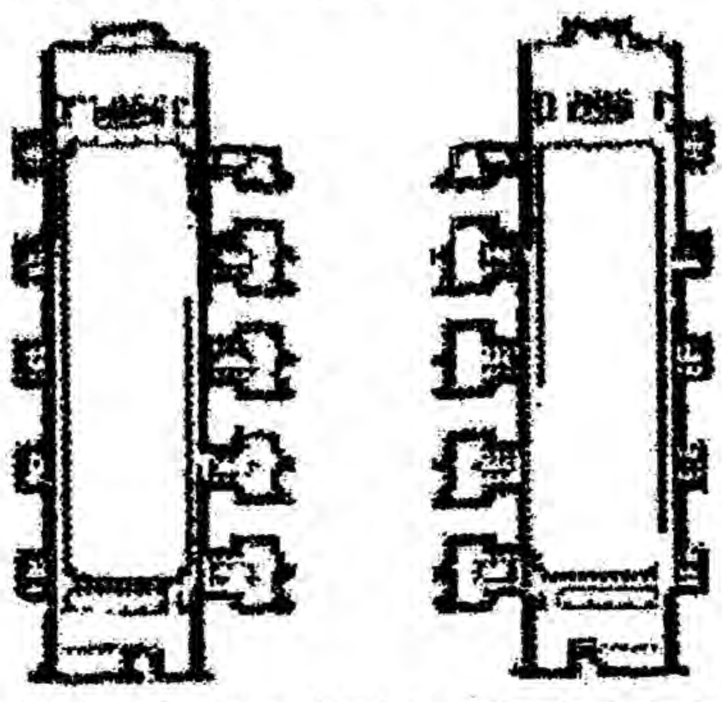

Figure 1.3.8 Part of the plan of the Salk Institute for Biological Studies[13]
Source: Gero, J., & Jun, H., Emergence of Shape Semantics of Architectural Shapes, Sydney, Australia.
www.arch.su.edu.au/~john/publications/KCDC/1996/ger-jun-emergence-epb.pdf

[12] Cohen, Jon, Designer Labs: Architecture Discovers Science, Science 2000, Volume 287, Number 5451, Issue 14/1/2000 in News Focus, p. 212.
[13] The researcher has found real difficulty in finding the plan of the institute, as although the Salk Institute is mentioned on most literature about research laboratories and about Louis Kahn, yet photos of it are always displayed and not architectural plans. This plan is from a paper about the evolution of form in architecture and not about the Salk Institute in particular.

while **figure 1.3.8** represents a section in the interstitial space and **figures 1.3.9–1.3.12** represent different views of the Salk Institute for Biological Studies, at La Jolla , California, which was completed between 1959-1965.

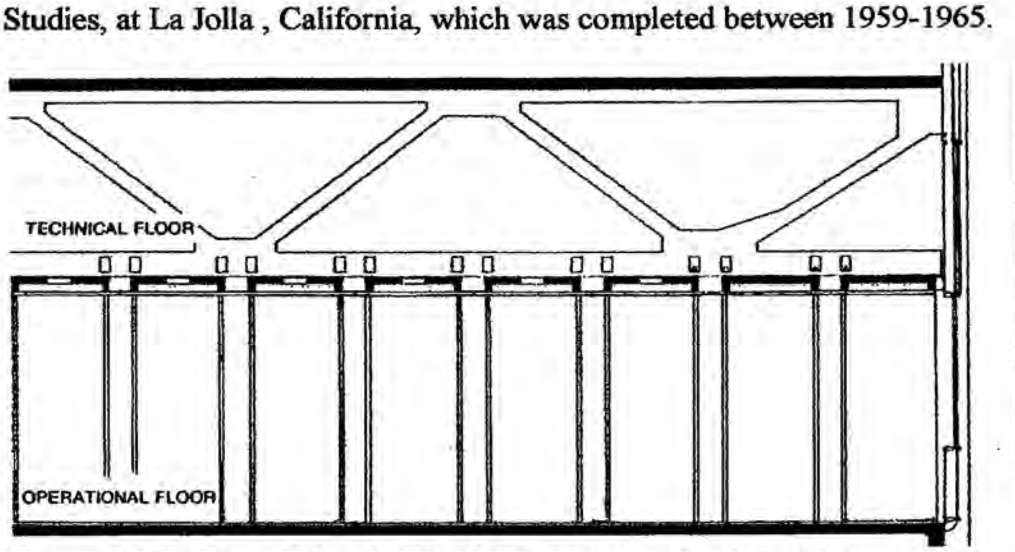

Figure 1.3.8 Louis Kahn & Earl Walls: The introduction of interstitial space
Source: Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA. 1986.

The Salk Institute became the world's most celebrated laboratory and an icon for laboratory design. Its centrepiece is a rectangular, travertine marble courtyard flanked by two mirror image, concrete and teak buildings. Water coursing down a gutter that cuts through the courtyard splits into four waterfalls that appear to spill into the Pacific. The institute's interior may be less recognisable but, unlike the Richards, it has won plaudits for being functional.

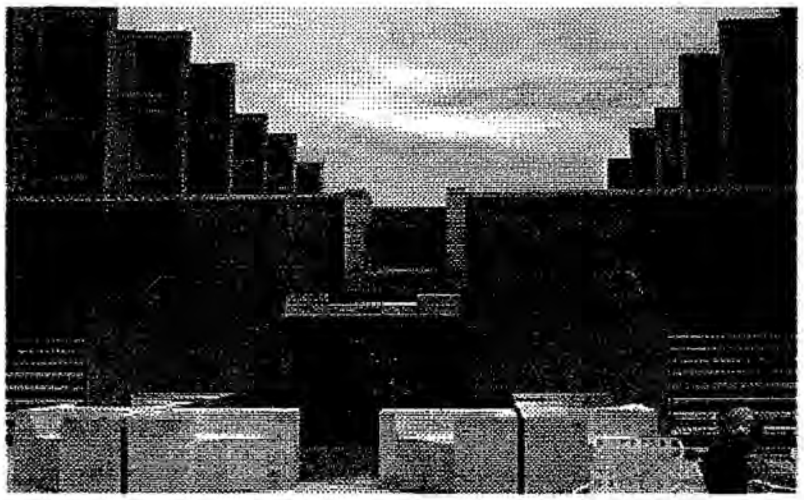

Figure 1.3.9 The Ocean View of the Salk Institute
Source:http://www.greatbuildings.com

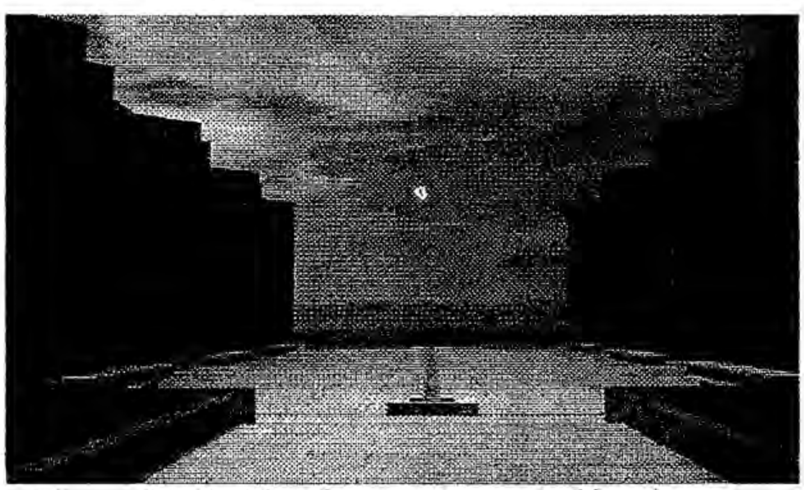

Figure 1.3.10 A break out space overlooking the ocean
Source:http://www.greatbuildings.com

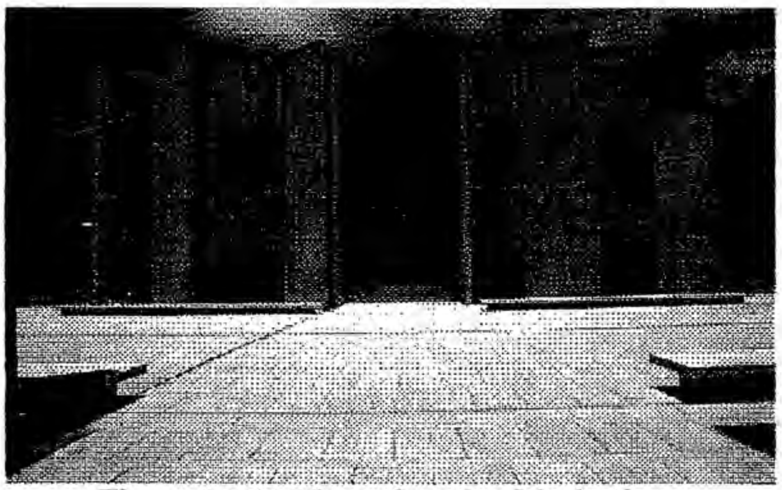

Figure 1.3.11 View of a unit of the institute
Source:www.bc.edu/bc_org/avp/cas/fnart/fa267/kahn.html

Figure 1.3.12 Exterior view of the Salk Institute
Source: www.bc.edu/bc_org/avp/cas/fnart/fa267/kahn.html

These are Kahn's words in describing his design:

> *"I did not follow the dictates of the scientists, who said that they are so dedicated to what they are doing that when lunchtime comes all they do is clear away the test tubes from the benches and eat their lunch on these benches. I asked them: was it not a strain with all these noises? And they answered: the noises of the refrigerators are terrible; the noises of centrifuges are terrible; the trickling of the water is terrible. Everything was terrible including the noises of the air-conditioning system. So I would not listen to them as to what should be done. And I realised that there should be a clean air and stainless steel area, and a rug and oak table area. From this realisation form became. I separated the studies from the laboratory and placed them over gardens. The garden became outdoor spaces where one can talk. Now one need not spend all the time in the laboratories. When one knows what to do, there is only little time one needs for doing it. It is only when one does not know what to do that it takes so much time. And to know what to do is the secret of it all."*[14]

What Louis Kahn described here is the attitude of scientists as clients all over the world, when they prepare an architectural brief, they do not ask for a café, for instance, they think they could eat and drink in their laboratories. But Kahn analysed their discomfort in eating in labs and designed for them a café

[14] from www.greatbuildings.com, March 2003

and an outdoor area. That is why the Salk is a success in many different ways.

1.4 Space Ergonomics of the Research Laboratory

The first laboratory buildings were built as conversions of rooms in existing buildings and purpose-built laboratories began to be designed much later; but even early labs began to exhibit the kind of space ergonomics current today. In a drawing of Liebig's teaching lab at Giessen in Germany, around 1842, shown in **figure 1.4.1**, there were fixed benches along two walls, with cupboards and drawers under them as well as shelves over them, and in the centre, two rows of heavy tables with drawers.

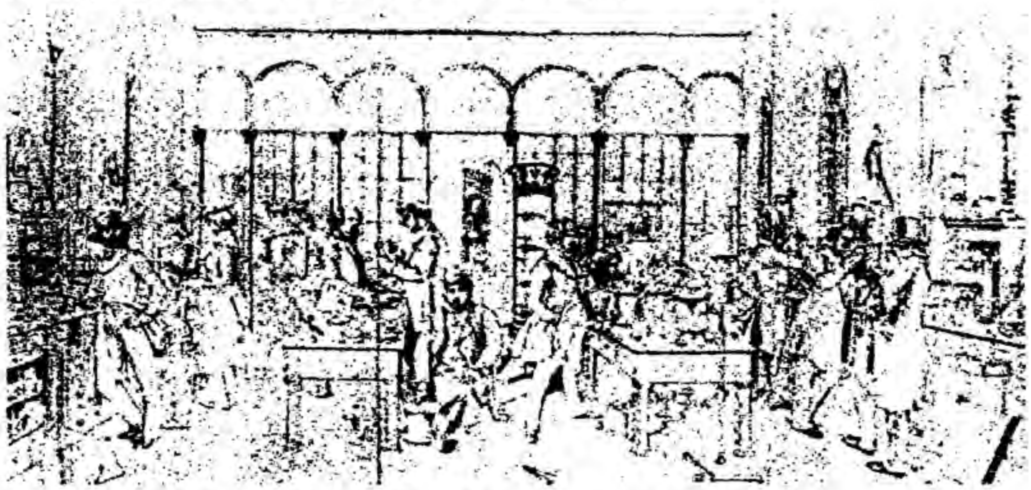

Figure 1.4.2 Liebig's teaching laboratory at Giessen in Germany around 1842.

Source: Braybrooke, S., (Ed.) *Design for Research, Principles of Laboratory Architecture*, John Wiley and sons Inc., USA. Preface, p. xii. 1986

The space between the benches and tables is about 1.8 m approx., benches are about 60cm deep and the tables are about 90cm deep. Every horizontal level is covered with apparatus; some stand on the floor and some on the top of cupboards. The scene is very familiar to this day. As for the bench layout, all the long sides are parallel and about 1.8m apart, thus responding to clear ergonomic necessities. Scientists can work at the benches, back to back and someone can walk between them.

1.4.1 The Nuffield Study

In the late 1950s, the Nuffield Division for Architectural Research carried out one of the first comprehensive studies about the design of laboratories. The guidance it produced is still being used today. The research was aimed at determining the amount of space and service facilities used by scientists at the bench, the proportion of time spent on reading and writing; physical characteristics of the laboratory environment and the rational lighting criteria. A lot of research was invested on the design of the lab unit layout. The research method used was that all aspects of bench scale for wet research laboratory were studied through a detailed series of case studies of working laboratories over a five-year period. The method centred on following selected individuals in each of the labs for a full year, visiting them unexpectedly at least four times during the year and noting exactly what they said they were using at the time of the visit. In this way it was hoped a true picture of the individual's space needs of services would be formed, as these varied over time. The findings and guidance were in two main forms, as percentages of the time a given run of benches (number of gas taps, etc) would satisfy a user, and in the form of a building design that synthesised all the guidance. This has become known as the **Nuffield Plan Laboratory**. The relationships investigated were between scientists and the lab space, benching and equipment that they were using at the times of the visits. This gave rise to predictable findings like, for example, that all space, wherever it was located, would be more conveniently located in a single straight run of benching in one location. Such guidance, although considered un-preceded at the time, turned to be lacking any spatial component, only lab space ergonomics.[15]

Most design guidance written about research laboratories in that period and even till this day focus mainly on laboratory programming, planning, design criteria, environmental and technical aspects of designing research laboratory buildings like servicing and structure[16]. Other factors also emphasised are flexibility[17], durability[18] and safety[19] factors. They are regarded as key problem areas for highly serviced buildings. They are important factors that have to be taken into consideration and there is a lot of literature covering those factors. This can be demonstrated through the writing of Weeks. He stated on the design of a research laboratory:

[15] The Nuffield Foundation Division for Architectural Studies, *The Design of Research Laboratories*, OUP, London, UK (1954-1961).

[16] Coleman, H. S., *Laboratory Design, National Research Council, Report on Design, Construction and Equipment of Laboratories*, Reinhold publishing Corporation, New York, 1951 and
Mayer, Leonard, *Design and Planning of Research and Clinical Laboratory Facilities*, New York, John Wiley and Sons.

[17] Griffin, Brian, Laboratory Design Guide, Architectural Press, 1998.

[18] Mayer, Leonard, *Design and planning of Research and Clinical Laboratory Facilities*, New York, John Wiley and Sons.

[19] For example: Diberardinis et al, *Laboratories-Safety Measures*, John Wiley and Sons, New York, 1947and Diberardinis et al, *Guidelines for Laboratory Design: Health and Safety Considerations*, John Wiley and Sons, New York, 1987.

> *"An empty space, a building shell, can be a laboratory if the right services can be provided. A laboratory, a hospital and an office building can all utilise the same basic building shell if the shell has certain characteristics."*[20]

As can be noticed, nothing was mentioned about the layout of the building or the spatial relationships that it should entail, which was not ignored only by Weeks, but by a whole generation. The spatial layout of the laboratory was and is addressed only at the level of metric space standards and in terms of ergonomic discussions leading to 'ideal' bay modules for the location of structure, servicing and benching. Literature has almost ignored social issues like communication and social interactions between researchers which was not mentioned or taken into consideration in designing research centres, until the emergence of the revolutionary research produced by Thomas Allen in the 1970s.

1.5 Communication and Problem Solving

First it has to be acknowledged that there is a tremendous difference between interacting face to face and all other forms of interaction. There has been a lot of research covering this subject. Physiology and cognitive science argue that the brain in general and the memory in particular work by association, and that interaction with others stimulates new associations, new connections that

[20] Lees, R., Smith, A.F. Ellis (Eds.), design, construction and refurbishment of Laboratories. Horwood Ltd., 1984, Chapter 2, p.35.

sometimes lead to breakthrough concepts. [21] Nuances of tone, inflection, timing, cadence, body language, attention, smell and facial expression are all richly present in any encounter, while they are captured only partially- if at all- in interactions via telephones and computers. From our experiences, we know that these factors contribute enormously to the completeness of exchange, to our ability to communicate effectively with one another. This is not to say that telephones and computers do not have their uses, but it does say clearly that here is something unique about encountering each other in the flesh.[22]

In the late 1970s, Thomas Allen[23], Professor of Organisational Psychology and Management at MIT's Sloan School of Management, wrote what is still the definitive book on interaction in the laboratory-based organisations. He studied factors influencing communication & innovation in research & development[24] (R&D) organisations in engineering. Through his studies of defence research projects in the USA, where routinely two independent teams get commissioned with the same brief and routinely their design solution tested, he concluded that problem solving and significant advances in knowledge depend much more on interaction between people that are not part of the same research group, profession or field, than on communication within work groups. His statement is supported by detailed empirical studies that have demonstrated that the most significant advances in engineering

[21] Calvin, William H., R, *The River that Flows Uphill: A journey from the Big Bang to Big Brain.* New York, MacMillan, 1986.
[22] Morris, Langdon, Social Design: The Link Between Facility Design, Organisation Design and Corporate Strategy. February 1999. www.innovationlabs.com
[23] Allen, T.J., *Managing the Flow of Technology.* Cambridge: MIT Press, USA, 1977, p. 123
[24] Research & development will be referred to by R&D.

knowledge appear to have a random component, which often depends on chance meetings between people that work in the same building or for the same organisation. To quote his words:

> *"Despite the hopes of brainstorming enthusiasts and other components of group approaches to problem solving, the level of interaction within the project group shows no relation to problem-solving performance. The data to this point lend overwhelming support to the contention that improved communication among groups within the laboratory will increase R&D effectiveness. Increased communication between R&D groups was in every case strongly related to project performance. Moreover, it appears that interaction outside the project is most important. On complex projects, the inner team cannot sustain itself and work effectively without constantly bringing new information from the outside world... such information is best obtained from colleagues within the organisation. In addition, high performers consulted with anywhere from two to nine organisational colleagues, whereas low performers contacted one or two colleagues at most."*[25]

Alan also notes the following about the kinds of interaction:

> *"Interactions may be recreational, such as playing bridge during lunch or discussing a weekend trip, or they*

[25] Allen, T.J., *Managing the Flow of Technology*. Cambridge: MIT Press, USA, 1977, p.123.

> *may be an outgrowth of work activity, such as borrowing tools or test equipments. In those interactions evolving from work situations the topics discussed are neutral; they don't involve the exposition of technical knowledge, or lack of it. These neutral social interactions, as well as the recreational activities, serve the important function of developing interpersonal understanding. Engineers indicated over and over again that understanding between colleagues was a prerequisite for effective technical communication."*[26]

Allen pointed out that both 'interaction-promoting facilities' and traffic patterns promote chance encounters and aid in the accomplishment of intended contacts. He noted that much of the traffic in a building is the result of the movement of people to and from certain types of facilities they must use during the course of a day- among them, toilets, copying machines, coffeepots, cafeteria, computer consoles, laboratories, special test equipment, supply rooms and conference rooms. These types of facilities vary with the functions and operations of any organisation. In all cases, they not only increase the occurrence of chance encounters among occupants of a building but often aid in promoting intended contacts by providing a person with more than one reason for travelling in particular direction. The presence of these facilities should be taken into account when locating organisational groups within a building.[27]

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[26] Ibid, p. 197.
[27] Allen, T.J., *Managing the Flow of Technology*. Cambridge: MIT Press, USA, 1977, p. 247.

Zewail[28], valuing his interactions with other scientists on campus, writes:

> *"We talked science, even while socialising. We used to go to a pizza parlour on campus... and then go back for late-night work."*[29] And *"We used to go out to an Italian café on campus for an hour's break to talk about work, the Middle East and the future."*[30]

Alan also discovered through his research that the increase in distance between people in an organisation reduces communication. Once the importance of face-to-face interaction is accepted as a design goal for an R&D lab, the obvious implication of this research is that everyone should not be away from everyone else. This translates that research labs should not be on large architectural plans and not on many floors. Allen pointed out that the number of floors in any research centre should not exceed three storeys in order to facilitate communication.

[28] Zewail, Ahmed, *Voyage through Time: Walks of Life to the Nobel Prize*, The American University in Cairo Press, Cairo- New York, 2002.
[29] Ibid, p. 59-60.
[30] Ibid, p. 75.

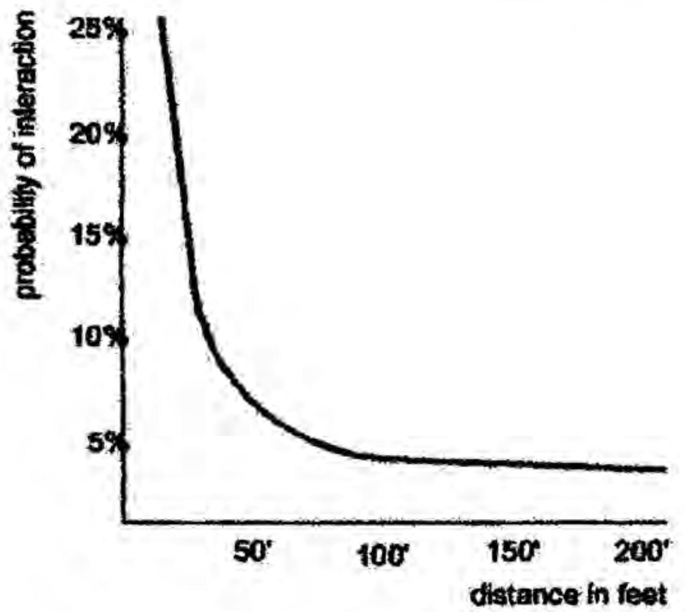

Figure 1.5.1 The probability that two people will interact as a function of the distance separating them. [31]

Source: Adapted from Allen, T.J., *Managing the Flow of Technology*. Cambridge: MIT Press, 1977, p. 241

Zewail describes Caltech, the university where he worked before and after he received the 1999 Nobel prize in Chemistry and how he is convinced by its model, being small in size. He writes:

> *"After going to Caltech, I began to have the Caltech model in mind because of its small size and its unusually high level of excellence."*[32]

[31] Morris, Langdon, *Social Design: The Link Between Facility Design, Organisation Design and Corporate Strategy*, 1999. www.kewaunee.com/lab-design.htm, retrieved from the internet in Feb 2003.

[32] Zewail, Ahmed, *Voyage through Time: Walks of Life to the Nobel Prize*, The American University in Cairo Press, Cairo- New York, 2002, p.79.

He also writes in clarifying his choice of Caltech among many American universities he was accepted to join:

> *"The class act at Caltech was unique and evident- the laboratories, the offices and the support staff are of the highest quality. And its smallness was attractive to me as I enjoyed the interactions with first-rate colleagues from different areas of science and engineering."*[33]

In 1982, Thomas Peters[34] extolled the virtues of organising office workers into large self managing teams, and went to suggest that many of the best ideas produced by these teams found their germination in unscheduled 'serendipitous' encounters with workers outside the team.

On the subject of the importance of social interaction, in studying social networks Granovetter[35] makes an important distinction between 'strong' and 'weak' ties between people in social networks. By strong ties he refers to friends that know each other, where both would cite each other in their network, and by weak ties he refers to acquaintances, friends of friends, and associations who normally do not know one another. He argues that weak ties thus act as bridges between localised clumps of strong ties and thus hold the larger system together thus also enlarging the individual's realm of support and information. Thus the wrong balance can be disadvantageous. He writes:

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[33] Ibid, pp.87-88.
[34] Peters, T.J. & Waterman, R. H. Jr., *In Search of Excellence*. New York: Harper and Row, Inc., 1982.
[35] Granovetter, M., The Strength of Weak Ties, in P.V. Marsden and N. Lin (Eds.), Social Structure and Network Analysis. Beverly Hills: Sage Publications Inc., 1982.

> *"Individuals with few weak ties will be deprived of information from distant parts of the social system and will be confined to the provincial news and views of their close friends. This will not only insulate them from the latest ideas and fashions, but may also put them at a disadvantaged position in the labour market... Furthermore, such individuals may be difficult to organise or integrate into politically based movements of any kind, since membership of movements in goal oriented organisations typically results from being recruited by friends."*[36]

Although Granovetter's work refers to social knowledge, while Allen's work refers to scientific knowledge, the two arguments are similar, in that both cast doubt on the long-assumed benefits of the spatial and social localism.[37] In 1991, Hillier and Penn[38] suggested the importance of the implementation of Granovetter's and Allen's arguments in work organisations. They argue that, just as it is important to create solidarity among members of the same field, it would be important to allow for the formation of weak ties between different professions and disciplines. The importance of creating solidarity among members of the same profession is not doubted, and in general terms,

[36] Granovetter, M., The Strength of Weak Ties, in P.V. Marsden and N. Lin (Eds.), *Social Structure and Network Analysis*. Beverly Hills: Sage Publications Inc., 1982, p.106.
[37] Hillier, B., Visible Colleges in *Space is the machine*, Cambridge University Press, 1996.p.256.
[29] Hillier, B., and Penn, A., Visible Colleges: Structure and Randomness in the Place of Discovery, Science in Context 4, 1, pp.23-49.

is something that most management of organisations aim at, but the importance of creating weak ties among members of different professions has received little formal attention.

1.6 The Architecture: Generative or Conservative Building Models

Hillier and Penn proposed that buildings, can set in place conditions for either the generation or conservation of knowledge. To the extent that spatial conditions maintain status, social relations, and through social practice, tradition can be maintained. In the case of the **generative** model, spatial conditions continually create new relational patterns by maximising the randomness of encounter through spatial proximity and movement. Space functions to facilitate and extend opportunities for encounter. This is particularly true, as the paper goes on to suggest, for building types where patterns of space use and movement are not highly structured by the building program; in such cases, and the research laboratory is considered to be one of these cases, movement is defined less by the program and more by the structure of the layout itself.[39] This leads to the importance of the architectural plan on the whole rather than just the relationships between individual rooms or the layout of the lab itself.

In studying the floor plans of two research laboratories both belonging to well-known British organisations where each has a distinctive research style and management structure, but one turned out to be higher in terms of its

[39] Hillier, B., and Penn, A., Visible Colleges: Structure and Randomness in the Place of Discovery, Science in Context 4, 1, p.26.

members receiving 'Nobel Prizes', Hillier and Penn[40] argue that the space in which interaction between lab users take place, has a profound effect on localising or globalising interaction. In lab1, see **figure 1.6.1**, the doorway between labs which is considered the interaction space, is at the end of the lab, near the window so it is away from global movement happening in the corridor. In lab2, see **figure 1.6.2**, the doorway between labs lies next to the main corridor so it is close to global movement. In the latter the chances of random interaction occurring between people moving in corridors and researchers of two or more adjacent labs are much higher, which helps much greater in problem solving according to Allen's research as colleagues from outside the research group get involved in interaction inside the other colleagues' labs.

1.6.1 Kinds of Movements in a Research Laboratory Building

Hillier[41] identified four patterns of activities as occurring in a research laboratory:

1) Contemplative activities (such as sitting, writing).
2) Practical activities (such as working at the laboratory bench, which usually involves a certain degree of local movement).
3) Interactive activities (such as conversing or taking part in discussions).
4) Non-local movement (linear large scale movement).

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[40] Hillier, B., and Penn, A., Visible Colleges: Structure and Randomness in the Place of Discovery, Science in Context 4, 1, p.26.

[41] Hillier, B., Visible Colleges, *Space is the machine*, Cambridge University Press, 1996, p. 261.

Figure 1.6.1 The empty spaces of Lab1 outlined in black. Note the interaction space between labs are near the perimeter of the building away from the main corridor

Source: Hillier, B., and Penn, A., Visible Colleges: Structure and Randomness in the Place of Discovery, Science in Context 4, 1, p.43

Figure 1.6.2 The empty spaces of Lab2 outlined in black. Note the interaction space between labs are near the main corridor

Source: Hillier, B., and Penn, A., Visible Colleges: Structure and Randomness in the Place of Discovery, Science in Context 4, 1, p.44.

In a study of large open plans of professional design offices, Backhouse & Drew[42] used careful observations and video recordings to look at the behaviour of workers engaged in work-related interaction. They found that when an individual is at his workstation he is usually regarded by others as engaged in work and should not be interrupted. However, should that individual leave his workstation to move to some other area whether or not that movement is dictated by the needs of work, he is regarded as 'free' and so available for 'recruitment' into interaction. Interestingly, not only does the recruited undergo a task-reorientation, but they argue that the recruiter must also change his task as he cannot have planned or expected the appearance of the recruited. In that sense a clear division is apparent between the organisation of planned immediate work and the unplanned, contingent achievement. As such the accomplishment of 'work' is often a contingent and unplanned process. They write:

> *"In plotting the movements of individuals when away from their workstations we found a markedly high incidence of 're-routings'- cases where a person notably deviated from his route of prior intention at the behest of another, or in order to recruit another person into interaction. As an individual moved into the vicinity of a 'significant' other, he would be (a)engaged or 'recruited', (b)his task orientation would be altered from the planned to the contingent, and (c)his prior task would become relegated to become a task 'pending' attention. The evidence of this*

[42] Backhouse, A., & Drew, P., The design implications of social interaction in a workplace setting, *Environment and Planning B: Planning and Design*, 1990. p. 16-17.

> *was found in the high incidence of individuals responding to verbal and non-verbal recruitments, and altering their intended course of action to accommodate such recruitment. Interestingly, not only does the recruited undergo a task of reorientation, but the recruiter must also change his task as he cannot have planned or expected the appearance of the recruited. In this sense a clear division is apparent between the organisation of planned immediate work and the unplanned, contingent achievement. As such the accomplishment of 'work' is often a contingent and unplanned process."*[43]

This zooming in on interaction in the workplace suggested by the study of Backhouse and Drew proposes that movement has some involvement in the work process which has not been pointed to before. And since movement is a by-product of the spatial organisation of a building, then the layout of the building plays a very sensitive role in the structuring of movement in a workplace. Hillier warns against the structuring of workplaces with efficiency only in mind. He writes:

> *"This will produce groups within the organisation that would reflect the current understanding and existing state of knowledge. People that the management believes need to interact will be placed within a group, those between whom*

[43] Backhouse, A., & Drew, P., The design implications of social interaction in a workplace setting, *Environment and Planning B: Planning and Design*, 1990. p. 16-17.

> *seems to be no rational need of interaction may be separated. Steps may even be taken in the interest of organisational 'efficiency' to minimise the need for movement on the part of staff by making sure that all facilities required for work are conveniently located near to each group. These would seem to be reasonable steps to take in order to produce a rational and efficient building plan."*[44]

Hillier suggests that although the existing state of knowledge in a field is a good starting point for problem solving, but it is not for innovation. Also because members of a group will be seldom interacting with people outside that definition of knowledge, in the interest of efficiency, the boundaries of knowledge will seldom be challenged or broken. In this sense, Hillier suggests that organisational efficiency and true innovation run counter to each other. He writes:

> *"Innovation requires probabilistic interaction and the opportunity to recruit, provided by bringing the larger-scale movement structure closer to the workstation. Moreover it requires that the larger-scale movement takes people with knowledge in one field past people with problems to solve in another. In this way it seems possible that the spatial configuration of buildings and the disposition of the organisations that inhibit them are*

[44] Hillier, B., Visible Colleges in *Space is the machine*. Cambridge University Press, pp. 270-271, 1996.

actively involved in the evolution of the boundaries of scientific knowledge itself."[45]

With all these ideas in mind, the layout of the building of a research laboratory along with an understanding management can have a tremendous effect in bringing people together and past each other's lab or workstation and thus generating *new* knowledge or have the opposite effect of keeping every group together away from all other groups and thus conserving old knowledge.

Summary

This chapter reviewed two research laboratory buildings belonging to two different generations of evolution of research laboratory design, the Bell Telephone Laboratories and the Salk institute of Biological Studies. The chapter also reviewed Thomas Allen's research on problem-solving performance in American R&D organisations has to do directly with consultations with colleagues from the same organisation but from outside the research group. Hillier & Penn pointed out the role of the layout of the architectural plan in bringing the global movement to the laboratory, in other words, trying to bring problem solvers past scientists with problems. Hillier warned against organisational 'efficiency' where further localisation can be achieved, instead of globalisation. Allen's work and Zewail's writings suggest that small plans are better for face to face communication and social interaction among scientists in a research laboratory. The aim of any research

[45] Ibid, pp. 270-271.

management should be to encourage the occurrence of social ties among the staff of the *whole* organisation.

In the following chapters different research laboratories are going to be architecturally reviewed and spatially analysed in order to try and pin down how they work and whether they are generators of new knowledge or conservators of old knowledge and how the public spaces mentioned by Allen have effects in promoting interaction in these research laboratories.

Chapter Two

Space Syntax Methodology and Analytical Tools 39-53

2.0	Introduction	39
2.1	Definition of Space Syntax	39
2.1.1	The Methodology	40
2.1.2	The Spatial Logic of Movement	41
2.2	Analytical Tools	42
2.2.1	Axial analysis	42
2.2.2	Boundary analysis	46
2.2.3	Justified Permeability Graphs	48
2.3	Summary	53

Introduction

This chapter introduces the space syntax approach and methodology of investigating architectural objects. **Part 2.1** defines the aim of "Space Syntax" in the context of the present architectural discourse. **Part 2.2** defines the elements of the spatial description that provide the basis for spatial analysis, carried out by a numerical measurement of spatial properties.

2.1 Definition of Space Syntax

Space syntax was born in the late 1970s in a research unit, not a design studio, the Unit for Advanced Architectural Studies at University College London, under the direction of Professor Bill Hillier. The research staff, as well as the majority of students attracted to the MSc degree & doctoral studies in the Unit for Advanced Architectural Studies, were and still are architects.[1]

By the late 1980s, the link between description and conceptualisation was firmly developing in a parallel field, over design proposals rather than research propositions, as space syntax got a voice around the design table and as, at UCL, the Unit for Architectural Studies mutilated into the Space Syntax Laboratory and Space Syntax Limited. The story of how analytical descriptions have interacted with design diagrams, design ideas and design conceptualisations has yet to be told and be opened to academic discussion and criticism.[2]

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[1] Peponis, John. 'Interacting questions and descriptions: how do they look from here?' Proceedings of the 3rd Space Syntax Symposium, Atlanta, Georgia, USA, May 2001.p.1.
[2] Ibid, p.1.

There was Sir Norman Foster's word in the opening address to the 1st Space Syntax International Symposium to set the agenda. He stated that the techniques of syntax "*are, in a way, experiments in the interaction between those two opposite worlds, of analysis, of observation, of reason, of research*" and "*of passion, feeling, intuition, imprecision and the hunch*".[3]

2.1.1 The Methodology

Space syntax is a theory of description applied to the built environment. It deals with the relational patterns that arise as space is marked, divided, enclosed, differentiated, shaped and organized by means of physical boundaries. Underlying this descriptive emphasis is a question exiled from architectural discourse for a portion of our recent past: how is built space to be understood as a social artefact, how does it function, how does it support or constrain behaviour, how does it reproduce social relationships, how does it generate social effects? The key towards a syntactic theory of function is provided by the description of space use as another kind of spatial morphology. Examples of generic morphological patterns that mediate between layout, social function and cultural meaning include: the functional labelling of spaces, movement, co-awareness, encounter and exposure to information. The word "syntax" bridges between the twin motivations to describe built space and its occupancy and to understand how these patterns are means through which we recognize and construct society and culture. As an analytical, quantitative and descriptive tool, space syntax is used to test

[3]Peponis, John. 'Interacting questions and descriptions: how do they look from here?' Proceedings of the 3rd Space Syntax Symposium, Atlanta, Georgia, USA, May 2001.p.1.

hypotheses in different domains of inquiry in which controlling for layout as variable is an issue.[4]

The depth of questions asked in space syntax meant that initially one could not easily dissociate judgement, "what is there to be described?" from technique, "how to do it?" These get better disentangled once the nature of the object is precisely conceptualised.[5]

2.1.2 The Spatial Logic of Movement

According to the most frequently scrutinized and empirically tested theories of space syntax, more integrated spaces are statistically associated with higher densities of movement. Peponis[6] writes: "*The correlation is not a mathematical artefact*" ... "*It is robust. It arises in cities without taking into account densities of development and patterns of land use; it also arises in buildings without taking into account routine sequences of activities and functional programs.*"

Buildings accommodate encounter by providing spaces in which people spend time and meet. A critical distinction must be drawn, however, between meetings that are formally scheduled or deliberately decided and meetings which arise as by products of co-presence. The former are merely accommodated, in more or less appropriate settings. The latter, are quite significantly generated from space. Space syntax has been used to

[4] Peponis, John. 'Interacting questions and descriptions: how do they look from here?' Proccedings of the 3rd Space Syntax Symposium, Atlanta, Georgia, USA, in May 2001, p.1.
[5] Ibid, p.2.
[6] Ibid, p. 3

systematically study the morphology of the second, more probabilistic set of weakly programmed, informal, serendipitous encounters. Of course, spatial layouts do not determine whether people will interact, even less the content or relevance of their interaction. They play a much stronger role in determining whether people are available as resources to be noticed, observed, approached or addressed by other people.

2.2 Analytical Tools

A number of methodological tools have been developed at UCL for the description and analysis of complex buildings space. The most important ones are the **axial** and the **boundary/ convex analyses** and the **justified permeability graphs**.

2.2.1 Axial Analysis:

The axial analysis simply identifies the longest and fewest straight lines that pass through all spaces in a plan. **Figure 2.1a** shows an architectural plan and **figure 2.1b** represents its axial lines.

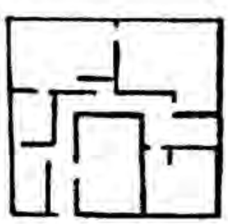


Figure 2.1a
An architectural plan

Figure 2.1b
Axial map of the same plan

The practical application of the technique is a computer simulation of spatial aspects of cities and of buildings. After a careful spatial description done manually by drawing the longest and fewest lines of sight and access, that can cover, in this case, the whole architectural plan, the computational analysis produces a distribution of the mathematical attribute that Hillier et al call 'integration'. Technically, the abstract 'axial lines' as they are called, are fed into the computer, where a specially designed programme called 'Axman' calculates the configuration of the line system. A mathematical measure is given to each line, where its value reflects its positional location or 'integration value' within the whole system. The use of such technique in analysis, is the comparative investigation of the underlying intrinsic logic under the appearance of order of architectural plans; that may affect or get affected by socio-cultural relations among inhabitants and visitors, among inhabitants and themselves in the use of buildings. This type of configurational modelling analysis technique according to Hillier[7] relates to understanding patterns of spatial relationships. He identifies three types of laws of space [8]:

"Type 1: *Laws governing the ways in which buildings can be aggregated to form towns or urban areas, that is, laws of the object itself.*

Type 2: *Laws of how society uses and adapts the laws of the object to give spatial form to different types of social relations, that is, laws from society to urban form.*

[7] Hillier, Bill, "Can Architecture Cause Social Malaise?" Paper given at the Medical Research Council, Seminar on Housing and Health, 15 Nov, 1991.
[8] Hillier, Bill, "The Architecture of the Urban Object". Ekistics, Jan./Feb. 334, March/April 335, 1989, p.5.

well as a comparison of **intelligibility values**. These comparisons should give an account of how integrated or segregated a floor is compared to other floors. Comparison of intelligibility values gives an account of whether a floor is highly intelligible, i.e. understood by visitors and users or less intelligible, i.e. people get lost in it easily. Those two measures should show significant results for the axial analyses of research centres.

2.2.2 Boundary Analysis:

The boundary analysis identifies the boundaries in buildings implemented by walls of rooms. **Figure 2.2a** shows an architectural plan and **figure 2.2b** identifies its boundary spaces.

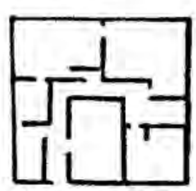


Figure 2.2a
An architectural plan

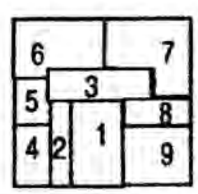


Figure 2.2b
Boundary map of the same plan

Integration of **figure 2.2b** can be computed by a program called 'New Wave' which will be used throughout chapter four in this thesis to produce the boundary integration core of the floors of research laboratories under analyses; it takes boundaries or convex spaces represented by numbers and computes them to produce integration and connectivity values for each space. It is a case of translating the configurational relationships into numerical values where they can be expressed by placing a comma between permeable spaces written in a program called "Teachtext" as follows:

1,2

2,3,4

3,2,6,7,8

4,2,5

5,4,6

6,3,5,7

7,3,6,8

8,3,9

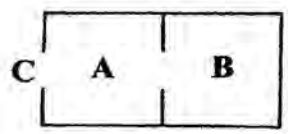
9,8

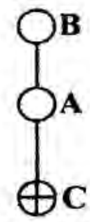
These relationships get computed by 'New Wave' program to produce a table. **Table 2.2c** is a result of the computation which is then arranged in a descending order of integration.

	Space no	Connectivity	Integration
1	3	4	2.218
2	2	3	1.478
3	7	3	1.267
4	6	3	1.267
5	8	3	1.109
6	4	2	.887
7	5	2	.887
8	1	1	.682
9	9	1	.591

Table 2.2c Spaces of **figure 2.2b** arranged in a descending order of integration (1/x RRA)

According to results from the previous table, the plan gets coloured according to integration colour codes as follows: Red represents the most integrated space followed by orange followed by yellow followed by green followed by blue followed by dark blue and finally followed by purple.





Figures 2.5a **Figure 2.5b**

Syntactic asymmetry: Asymmetrical configuration relationship exists between the three spaces A, B and C

Configurational difference can be represented by a clever device called a **justified permeability graph**.[10] This is a graph in which a particular space is selected as the "root" or "carrier" and all the spaces in the graph are then aligned horizontally above it in levels according to how many spaces must be passed through to arrive at each space from the root. Depth values determine how far removed each space in the complex is from the root, i.e. whether it is deep or shallow respectively. Thus **figures 2.4b & 2.5b** are justified permeability graphs of **figures 2.4a & 2.5a** respectively. Also figure **2.6b** is a justified graph of figure **2.6a**, where A and B are on the same level of depth from space C while space D is on a further level of depth from the two spaces A and B. Also there is a loop or ring occurring where permeability is continued from space C passing by A to D to B and back to C again. This property is called ringiness. Another form of ringiness can occur when two alternative routes can be taken from space A to B, like two doorways between two rooms which is demonstrated in figures 2.3c&d.

[10] Hillier, B., Hanson, J., *The Social Logic of Space*, CUP, 1984.

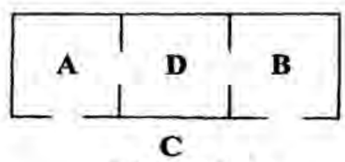


Figure 2.6a

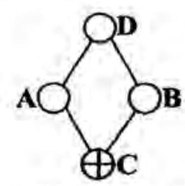


Figure 2.6b

Justified graphs of buildings show that space is organized in relation to two parameters, depth and rings.[11] There can be no more depth from a point in a configuration that a sequence, nor less than a bush. A tree has the least number of connections to join the configuration up into a continuous space pattern. Rings add extra permeability, up to theoretical maximum where every space is connected to every other. Regardless of depth, all graphs which are trees, that is, which have k spaces and k-1 links will have only one route from any space to any other. Alternative routes will therefore show themselves as rings in the graph as in **figure 2.6b**. Spaces can be distinguished from each other according to whether or not they lie on rings, how many rings they lie on, and which rings they lie on. Relative ringiness or the space-link ratio in a system can be measured by the number of links plus one, over the number of spaces, i.e.

$$\textbf{Relative ringiness} = \frac{\textbf{number of links+1}}{\textbf{number of spaces}}$$

Values above 1 indicate the degree of ringiness in a system[12] which can be compared to other systems.

---

[11] Hillier, B.; Hanson, J.; Graham, H., "Ideas are in things: an application of the space syntax method to discovering housing genotypes", Environment and Planning B, Volume 14, p, 364, 1987.

[12] A tree will have a value of 1.

Depth, however, will be used in a more developed and quantitive form which is called integration. The integration value of a space expresses the relative depth of that space from all others in the graph through the formula

$$\textbf{Integration value} = \frac{2(md - 1)}{k - 1}$$

where **md** is the mean depth of spaces, i.e. the number of spaces away from all other spaces from the selected space, and **k** is the total number of spaces from the selected space. A correlating factor is applied to eliminate the empirical effects of size, so that different systems may be compared. This measure is called **RRA** (real relative asymmetry). In theory this gives a value varying between 0 for maximum integration, that is no depth as in **figure 2.3b** and **2.4b** and 1 for maximum segregation, that is, maximum possible depth as in **figure 2.5b**. But in practice we use 1/x of RRA and call it integration. The higher its value the more integrated the space is, the lower the more segregated. The integration value of a space expresses numerically a key aspect of the shape of the justified graph if drawn from that space. In most spatial complexes, integration values will be different for different spaces and justified graphs will show this difference visually. **Figures 2.7a&b,** for example, are justified graphs of the **figure 2.1a** drawn from two different points. **Figure 2.7a** is relatively deep (depth 4) as it is drawn from the most segregated space where it happened to be the exterior while **figure 2.7b** is relatively shallow (max depth= 2) as it is drawn from the most integrated space in the system (the corridor).

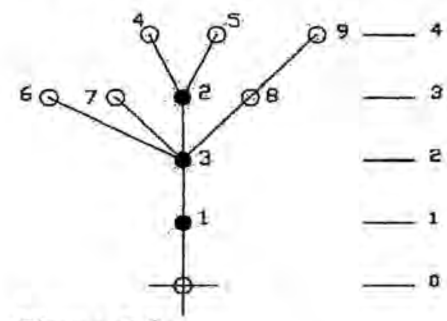


Figure 2.7a
Justified permeability graph drawn from the exterior

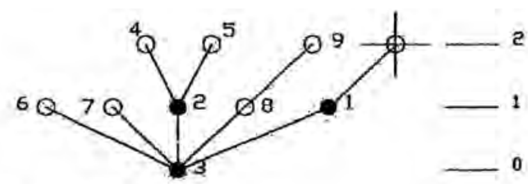


Figure 2.7b
Justified permeability graph drawn from the most integrated space

Differences in integration values are one of the keys to the way in which architectural relations express themselves through space. For example, different functions in a research laboratory are usually assigned to spaces which integrate the system to differing degrees. Function thus acquires a spatial expression which can be assigned a numerical value which can be quantitatively compared.

Summary

Part one of chapter two introduced a definition of the space syntax theory and gave an account of its application. Part two of the same chapter introduced the methodological tools of the space syntax theory which are the axial and boundary analyses. It introduced measures like integration, depth, ringiness, intelligibility and justified permeability graphs which will be extensively used in chapter four. Also in chapter four the defined syntactic descriptive tools and measures will be used as a basis for spatial analysis of the different research centres that are going to be architecturally reviewed in chapter three.

Chapter Three

Architectural Review of Selected Research Laboratories

54-168

3.0	Introduction	54
3.1	Architectural Review of Selected Research Laboratories	56
3.2	Comparative Analyses	152
Table 3.2a of Advantages and Disadvantages of the Egyptian Sample		153
Table 3.2b of Advantages and Disadvantages of the British Sample		154
Table 3.2c of Advantages and Disadvantages of the American Sample		155
Table 3.2d of Advantages and Disadvantages of the Japanese Sample		156
3.3	Discussion	157
3.3.1	Summary of the Egyptian Sample	157
3.3.2	Summary of the British Sample	159
3.3.3	Summary of the American Sample	160
3.3.3	Summary of the Japanese Sample	161
3.4	The Scoring Criteria	162
Table 3.4.1	Comparison of the Contents of Research Laboratories	165
Table 3.4.2	Summary of table 3.4.1 in percentages	166
3.5	Summary	167

3.0 Introduction

This chapter is going to present the architectural aspects of the research centres chosen for spatial analysis. The sample comprises of research centres that are laboratory-based organisations existing in Egypt and some other countries, such as the UK, USA and Japan. The Egyptian sample passes through a chronological order in the choice of samples; ranging from a relatively old building like the National Research Centre built in the thirties, to the Housing and Building Research Centre built in the sixties, to the Gamma Irradiation Facility built in the seventies, to the National Centre for Safety and Radiation Control built in the nineties and finally to the Institute for Genetic Engineering Research at Mubarak City for Scientific Research built in the late nineties. The sample from the other countries is relatively modern buildings all built in the nineties except for the Schlumberger Cambridge Research Centre completed in the early eighties.

This is a list of the names of the laboratories. The abbreviations that are going to be used to refer to them later on in the spatial analysis are underlined, with the place and the year of completion[1]:

1) The National Research Centre, <u>NRC</u>, Dokki, **Egypt**, 1956.
2) The Housing and Building Research Centre, <u>**HBRC**</u>, Dokki, **Egypt**, 1963.
3) The Gamma Irradiation Facility, <u>**GIF**</u>, Atomic Energy Authority, Nasr City, **Egypt**, 1975.

1 The researcher would have preferred the design date rather than the completion date but that was difficult to find for all samples.

4) The National Centre for Nuclear Safety and Radiation Control, **NCNSRC**, Atomic Energy Authority, Nasr City, **Egypt**, 1998.
5) The Institute for Genetic Engineering, **IGER**, Mubarak City for Scientific Research, New Borg El-Arab, **Egypt**, 1999.
6) Schlumberger Cambridge Research Centre, **SCRC**, Cambridge, **UK**, 1982.
7) Camelia Botnar Laboratories, **CBL**, Great Ormond Street Hospital, London, **UK**, 1993
8) Institute of Medical Sciences, **IMS**, University of Aberdeen, Scotland, **UK**, 1993.
9) Biological Sciences Complex, **BSC**, University of Georgia, Athens, Georgia, **USA**, 1991
10) Skirball Institute of Biomolecular Medicine, **SIBM**, New York University, New York City, **USA**, 1993
11) Rhone-Poulenc Rorer Research Centre, US headquarters, **RPRRC**, Collegeville, Pennsylvania, **USA**, 1994
12) Kazusa DNA Research Institute, **KDNARI**, Kisarazu City, Chiba, **Japan**, 1994.
13) Sandoz Tsukuba Research Centre, **STRC**, Tsukuba City, Ibaraki, **Japan**, 1993.
14) Bayer Yakuhin Research Centre, **BYRC**, Kizu Town, Kyoto, **Japan**, 1994.

In the following part each research centre is going to be architecturally reviewed individually.

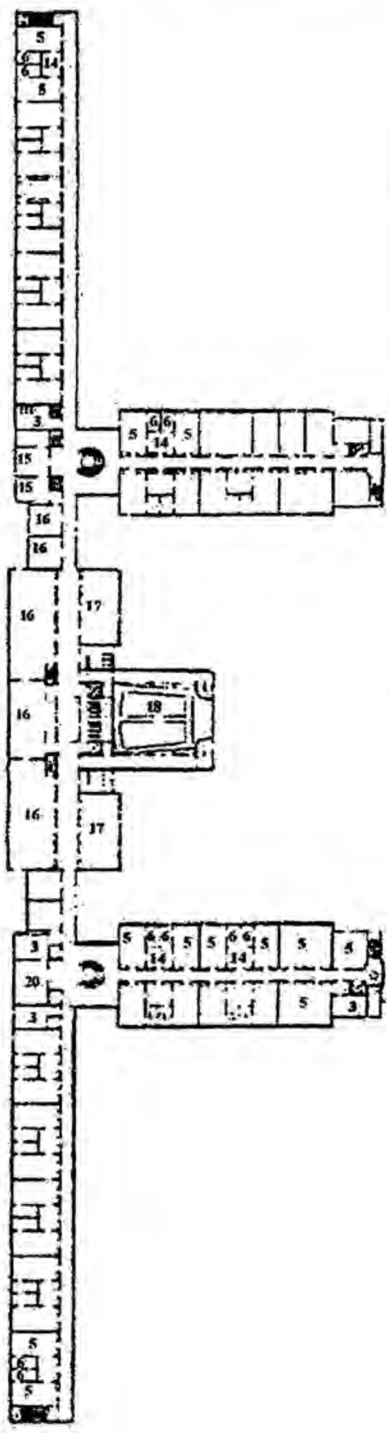
3.1.1 The National Research Centre, NRC, Dokki, Egypt, 1956

The idea of the centre originated in the late thirties[2] and it was designed and built in the mid fifties by the late Egyptian architect Ali Labib Gabr, to cover the needs of the nation for a research facility, in the branches of natural science, physics, chemistry and medicine. When it was built it was the biggest research facility in the Middle East.[3] Scientists working in this centre are multidisciplinary.

The building under study is the main and first building of the NRC complex that exists today. Many buildings were added to that building and they form a big complex known as the National Research Centre Complex whose site plan is represented in **figure 3.1.1.1**. **Figures 3.1.1.2a-f** are different views of the building.

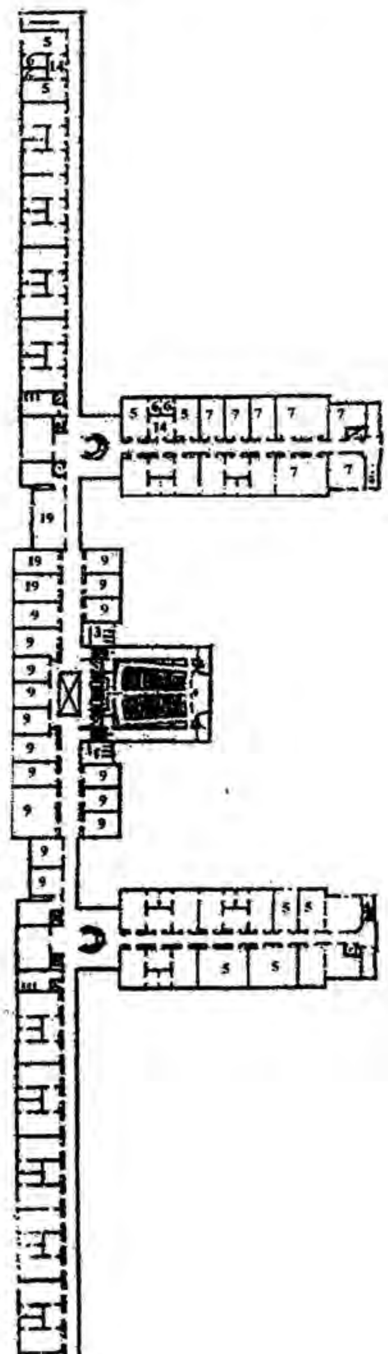
The main NRC building is a four-storey building. **Figures 3.1.1.3-3.1.1.5** represent the three floors of the building. It is a symmetrical building along a middle axis. The ground floor (see **figure 3.1.1.3**) is divided into three separate parts to allow passage of users to other parts of the complex. The central part comprises lecture halls, administration rooms and storage rooms. The two side-parts, which are two L-shaped buildings, comprise laboratories and storage rooms. The first floor (see **figure 3.1.1.4**) is a continuous floor with a long corridor connecting the whole floor. Perpendicular to that part are two symmetrical wings. The central part of the plan consists of a long library

[2] Mahmoud, M., K., Zayed, S., and Saber, M., *The History of Scientific Thought at the National Research Centre 1939/1998,* Alahram Publishers, 1998. P.18.
3 Hammad, Mohamed. *Egypt Builds*, 1963. P. 205.



3 WC
5 Laboratory
6 Office
14 Break out area
15 Photocopying
16 Library
17 Archives
18 Auditorium
20 Clinic/First aid

Figure 3.1.1.4 The first floor plan of NRC
Source: Hammad, Mohamed, *Egypt Builds*, 1963. P. 203.



5	Laboratory
6	Office
7	Storage
9	Administration
14	Break out area
19	Engineering section

Figure 3.1.1.5 The second floor plan of NRC
Source: Hammad, Mohamed, *Egypt* Builds, 1963, p. 205.

with a central reading room. Facing the library is a large auditorium. The rest of the floor consists of laboratories and offices for researchers. The unit of laboratory and office (see **figure 3.1.1.6**) starts with a common room that leads to two laboratories, each leads to an office and both are connected through a doorway. This unit is repeated throughout the whole building.

Figure 3.1.1.6 The lab & office unit of the NRC
Source: Hammad, Mohamed, *Egypt Builds*, 1963

The second floor (see **figure 3.1.1.5**) is similar to the first but in place of the library are administrative rooms.

1) Advantages of the design:

1) Low rise building which facilitates communication between users of different floors.
2) Break out areas open up onto the main circulation area (corridor) which facilitate interaction between scientists that are ready for interaction and passers by.
3) Research offices are located beyond labs to achieve privacy and quietness.

2) **Disadvantages of the design:**

1) Very long and symmetric plan.
2) The lack of meeting rooms, break out areas, cafés or any similar functions in the building.
3) The café and dining room situated in the branches building behind the main building are not big enough to receive the staff at lunch time. So to compensate for that lack of space the café introduced laboratory and office service which reduces the probability of researchers meeting in the café.

3.1.2 The Housing and Building Research Centre, HBRC, Dokki, Egypt, 1963

Designed by the late Egyptian architect Salah Zeitoun, it was built in 1954. Originally named "Building Research Institute" but recently in 1996 the name was changed to "Housing and Building Research Centre". The main functions performed by the centre are the following:

"1) Applied research in building related fields, housing, upgrading and environmental design.
2) Research, experimental facilities and consultations to assist the building sector.
3) Quality control testing, building inspection at the national level." [4]

Figure 3.1.2.1 represents the site plan of the centre.[5]

4 From a brochure by the HBRC promoting its functions.
5 All plans were taken from a publication about the HBRC from the centre's library.

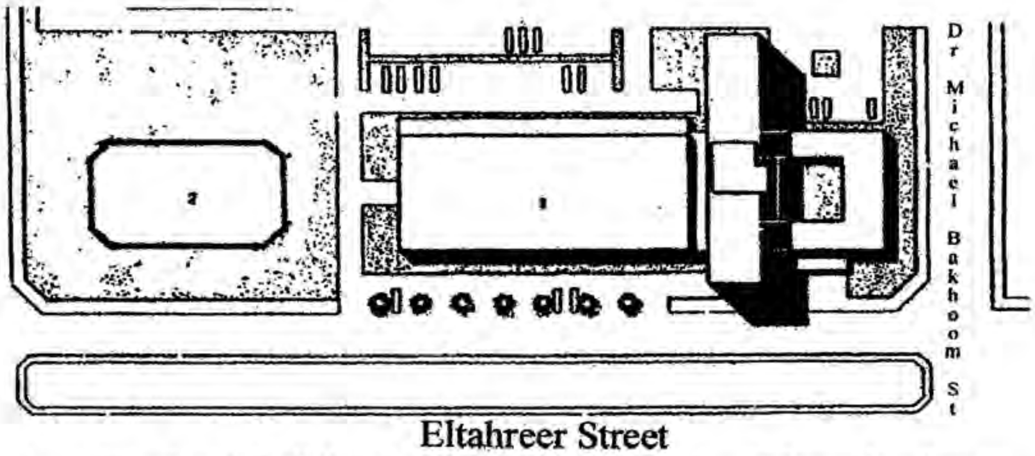


Figure 3.1.2.1 The site plan of the Housing & Building Research Centre
Source: A booklet about the HBRC

The ground floor is represented by **figure 3.1.2.2**. It comprises a spacious entrance hall overlooking a courtyard, security rooms, an auditorium, a binding and repair shop for publications, a kitchen, a café for workers, a mosque, a set of laboratories and offices opening onto a huge sky lit courtyard which is a laboratory hall for building materials where field experiments take place. **Figure 3.1.2.3** represents the first floor of the building. It comprises a library, a showroom for building materials, a restaurant, a set of laboratories and offices overlooking the courtyard. This is the floor chosen for spatial analysis. **Figure 3.1.2.4** represents the second floor of the centre, the north side of which contains chairman's office, meeting room, secretary and the south side of which contains administration rooms. **Figure 3.1.2.5** represents the third to the eighth floor which is the typical floor plan of the research centre, which comprises laboratories and offices. **Figure 3.1.2.6** represents an elevation of the research centre. **Figures 3.1.2.7a-c** represent different views of the research centre.

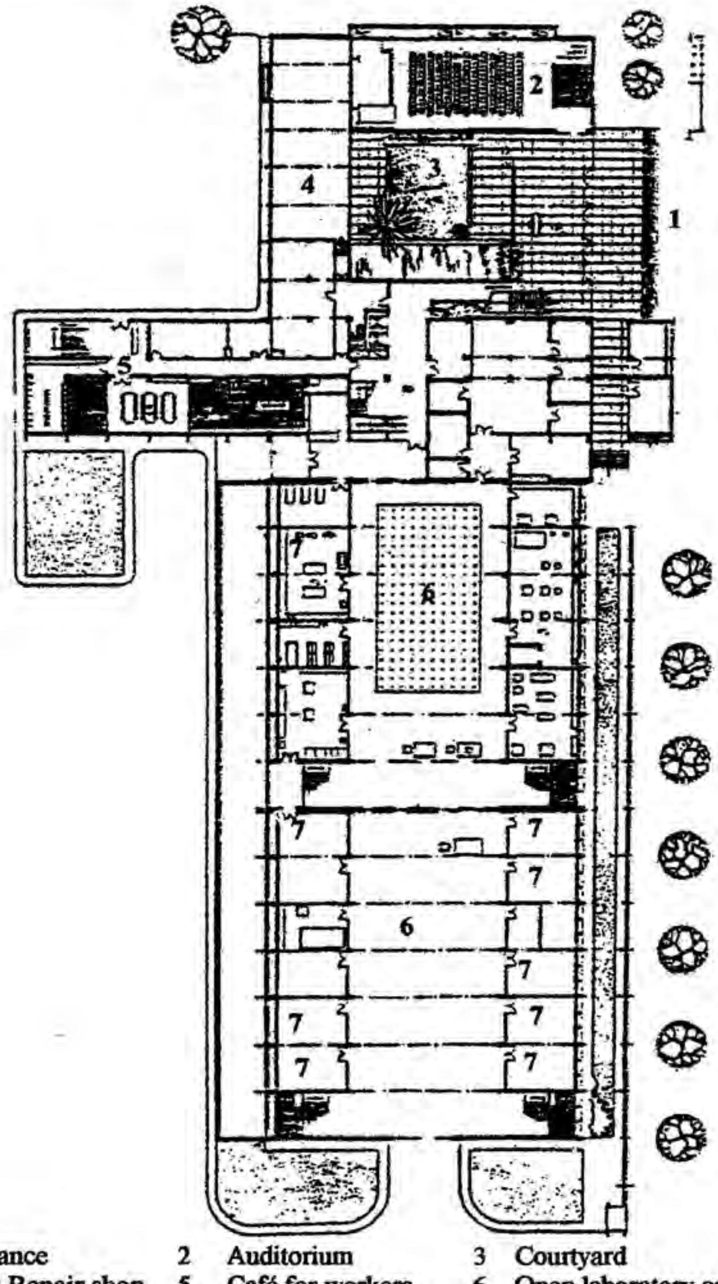
Advantages of the design:

1) All parts of the building are well lit.
2) Communication among researchers is well maintained in the left part of the building where the labs open onto and overlook the courtyard laboratory hall.
3) The one corridor based typical floor plan facilitates random interaction among researchers working in the same floor.

Disadvantages of the design:

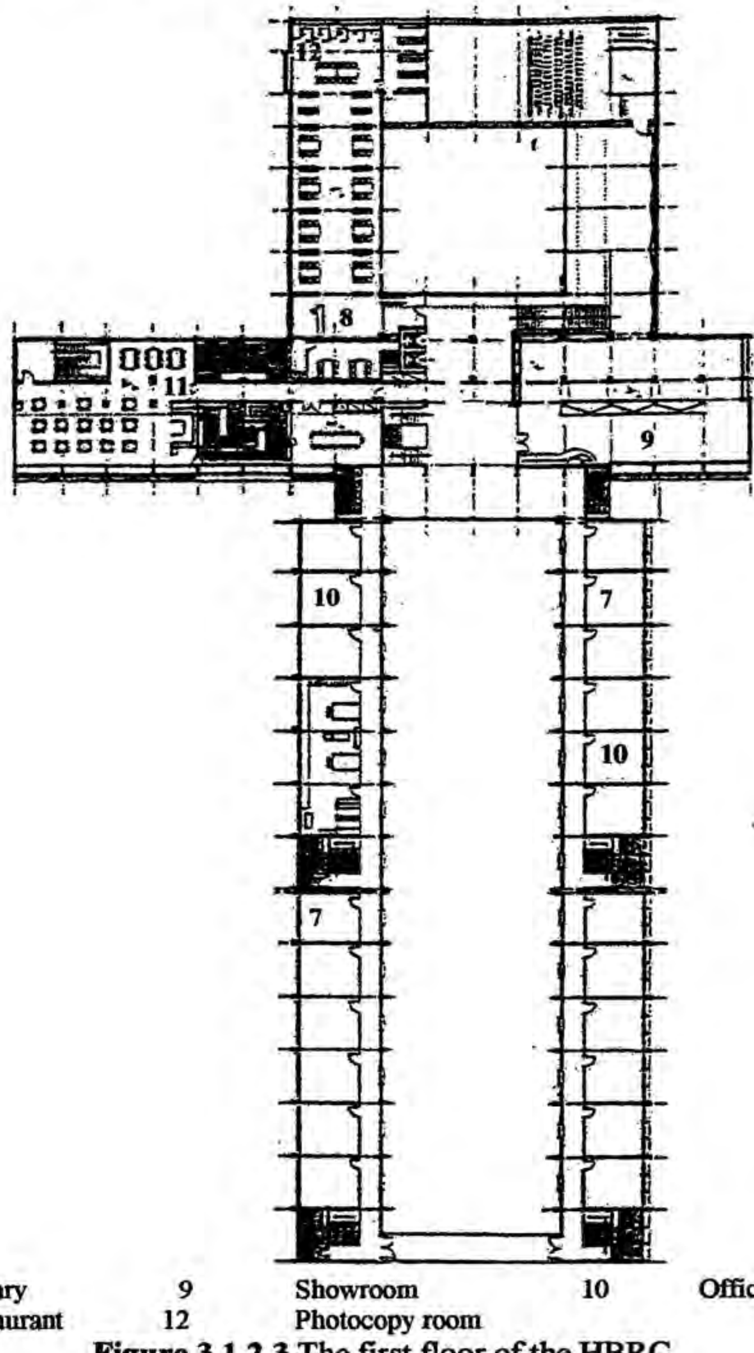
1) Lack of meeting rooms and break out areas.
2) Lack of coffee rooms on every floor.

The eight-storey building hinders communication among users of different floors as vertical adjacency is lost for users of the eight floors.



1 Main Entrance 2 Auditorium 3 Courtyard
4 Binding & Repair shop 5 Café for workers 6 Open laboratory courtyard
7 Laboratory

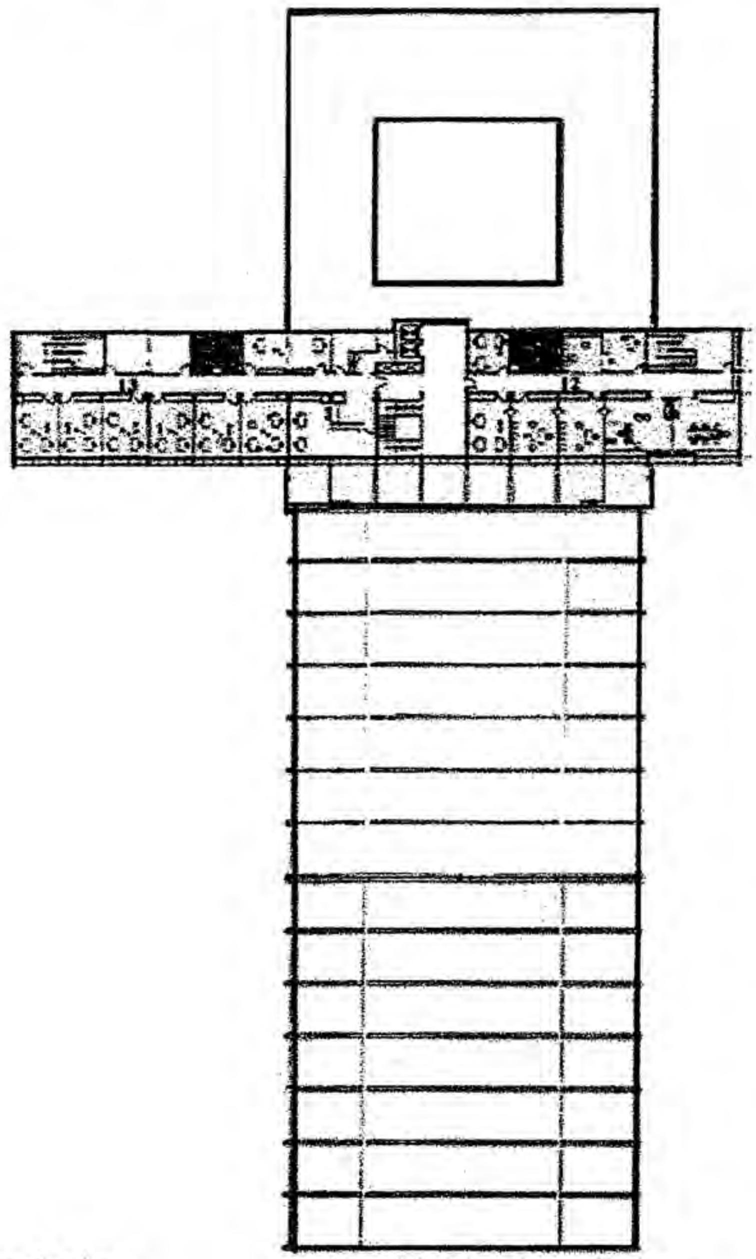
Figure 3.1.2.2 The ground floor of the HBRC
Source: A booklet about the HBRC



8	Library	9	Showroom	10	Office or lab
11	Restaurant	12	Photocopy room		

Figure 3.1.2.3 The first floor of the HBRC

Source: A booklet about the HBRC



12 Chairman's wing 13 Administrative staff wing

Figure 3.1.2.4 The second floor of HBRC is for administration
Source: A booklet about the HBRC

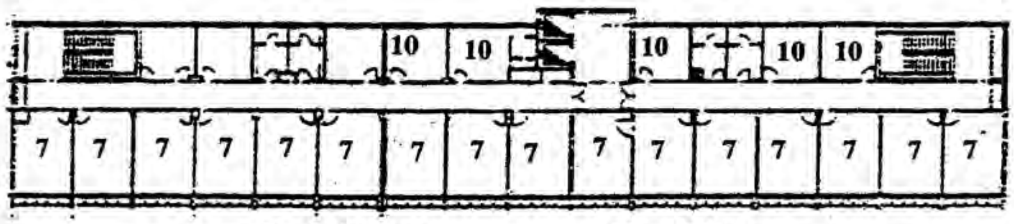


Figure 3.1.2.5 The third to eighth and typical floor of HBRC
Source: A booklet about the HBRC

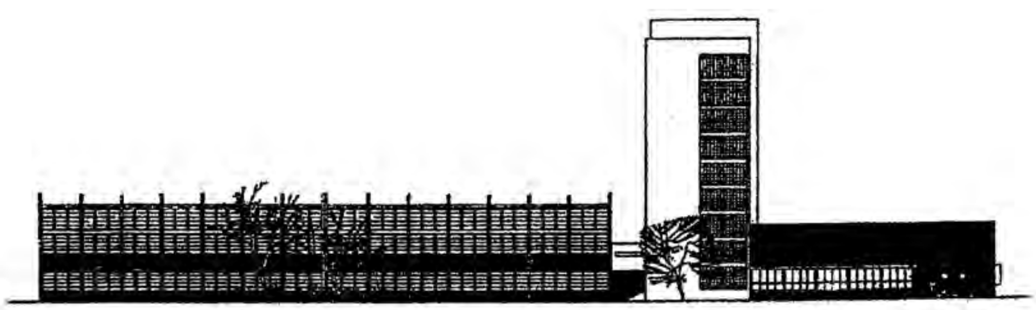
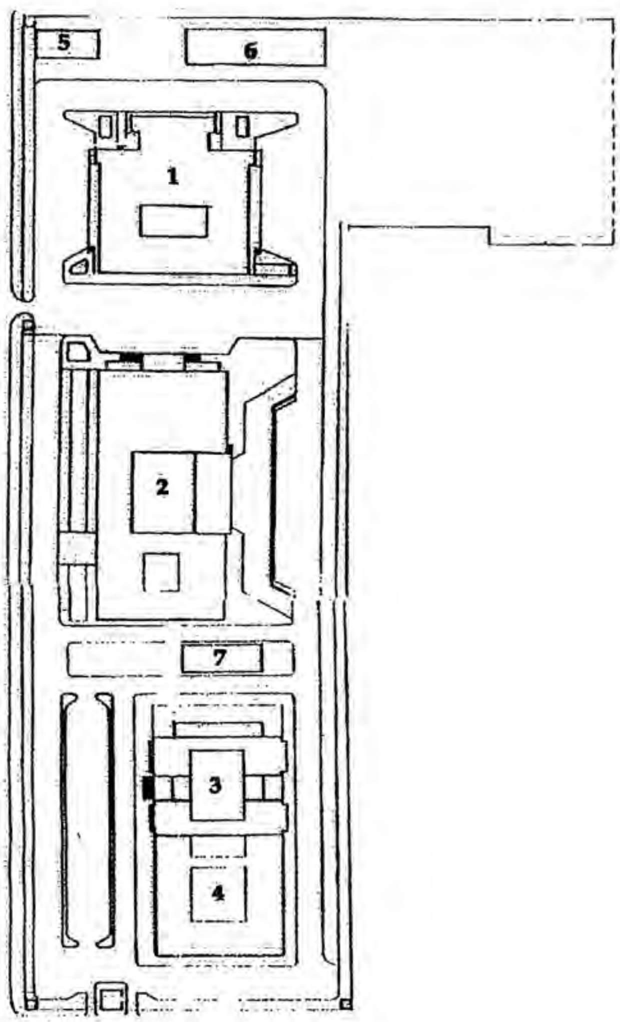


Figure 3.1.2.6 The north elevation of HBRC
Source: Ibid



1 The Gamma Irradiation Facility
2 The Electron Beam Accelerator Building
3 The Administration Building
4 The Conference Centre
5 The *old* building of the National Centre for Nuclear Safety & Radiation Control
6 The *new* building of the National Centre for Nuclear Safety & Radiation Control
7 The Electric Transformers Building

The buildings whose names are underlined are going to be spatially analysed in the next chapter

Figure 3.1.3.1 Site plan of the Atomic Energy Authority, Nasr City
Source: The engineering department at AEA.

Figures 3.1.3.2a&b are general views of the building. **Figure 3.1.3.3** represents the ground & main floor of the building. It consists of several (seven) entrances shown by numbers 1-7 in **figure 3.1.3.3**. The radioactive source is right in the heart of the floor in a central hall with a double height space. On the right hand side of it is the receiving of goods hall where the products to be radiated are collected and stacked ready for radiation. The products, which are put in boxes, stand on a conveyor belt and it takes them by turn to the radioactive source with a calculated speed where they get radiated and then come out to be stacked in the returning of goods hall ready for collection (see **figure 3.1.3.5**). Facing these halls is a longitudinal array of laboratories each opening on a hall. Most of these labs have been redesigned by their users in order to divide the lab into two spaces, an ante lab or office then a lab, where in the ante lab meetings with people take place.

To the north and south of the radiation source are two-storey buildings for laboratories. The one in the north has a rectangular plan with a double loaded corridor where its main entrance is in its middle. It houses a number of laboratories and research offices. It has also two side entrances and is designed around a long corridor with a central staircase overlooking a courtyard (see **figure 3.1.3.6**). **Figure 3.1.3.7** represents a view of the end of the right corridor in the North laboratory building.

Because of the need for new labs a number of them have been added by the management of the facility on the left hand side of the courtyard and on the west façade of the building (shown by shaded rooms in **figure 3.1.3.3**).

The building is mainly a one-storey building with a double height ceiling except for the North and South laboratories; they have another storey of laboratories. **Figure 3.1.3.4** represents the first floor of the GIF. The North one houses the chairman's office on one side and a set of labs on the other side. The South one houses a set of labs single loaded on a corridor that overlooks the double height space of the radiation hall.

Advantages of the design:

1) The limitation of height to one or two storey building facilitates communication.

Disadvantages of the design:

1) Because all buildings in the site are not linked, communication among researchers from different buildings diminishes.
2) The distance between the two sets of labs south and north of the facility decreases communication between researchers working in each of them, especially the south building, it encounters very natural movement as it is away from administration and isolated from all natural movement.
3) Lack of meeting rooms, break out areas, café, coffee rooms or any collective activities space at the level of the GIF or at the level of the whole site.

3.1.4 The National Centre for Nuclear Safety and Radiation Control, NCNSRC, Atomic Energy Authority, Nasr City, Egypt, 1998

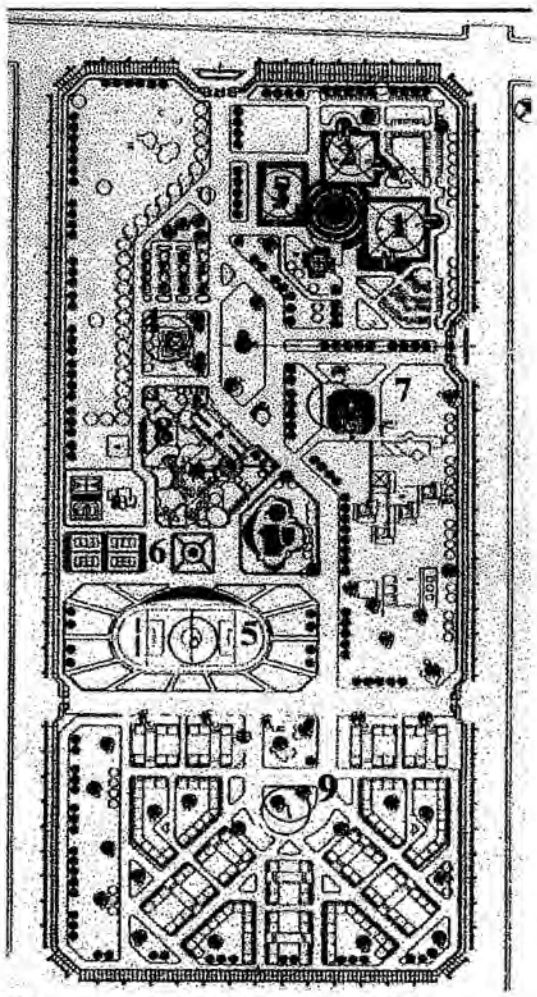
Founded in 1982, this centre's job is to construct laws to define the safety measures that must be taken when designing, building and operating nuclear power structures. Also it is an inspecting organisation that makes sure that specifications and rules are abided by all over the country. During the making of this thesis a new building for this centre was opened and all the scientific and research staff moved to it. The administrative staff was left in the old building. So the review is going to focus on building number 6 in **figure 3.1.3.1**. The research staff is grouped into departments according to specialisation. Similar specialists are grouped together in departments. Sometimes teams are formed from people from different departments according to specialisations.

Designed by the Arab Firm for Design and Architectural Consultations, AFDAC, the new building was completed by the year 1998. **Figure 3.1.4.1** is a general view of the building. It is a nine-storey building. Each floor from the third up to the sixth, houses two departments. Air conditioning is divided between the two sided on every floor so each side is serviced in a room on each side of every floor. The third floor was chosen for spatial analysis as it is a typical plan and consists of a number of laboratories and research offices. **Figure 3.1.4.2** represent the third floor and typical floor of the building.

The rest of the research park should in the future include some tennis courts, recreational areas and residential buildings for the research staff.
The building under study is building number one in **figure 3.1.5.1**, which is the biggest pyramid, the Institute for Genetic Engineering Research, IGER. The building number two is the Institute for Information and building number three is the institute for New Materials. Only 35 researchers work at IGER for the time being, 70% of whom are abroad for scientific purposes.[7] So when the researcher visited the building on a Sunday in January 2001, besides the dean, only a handful of scientists were present in the building.

Figures 3.1.5.3 a-d are different views of the building. It consists of five floors vertically connected by a round staircase and three lifts. On every floor above the basement and the ground floor, there is a fire exit connecting the floor to the street by a staircase enclosed in a vertical tower. **Figure 3.1.5.4** represents the ground floor of the building. The plan is square in shape: Labs occupy the circumference facing outwards while the research offices overlook each other through the courtyard and at every corner between offices there is a meeting room. Services like air conditioning, toilets and dark room occupy the left hand side of the plan. A formal seminar room occupies the left corner of the ground floor. The floor also houses some administration rooms and a waiting area. **Figure 3.1.5.5** represents the first floor of the IGER. Like the ground floor research offices overlook the inner courtyard while labs face outwards. The architectural drawings show meeting rooms in three corners but on a visit to the building in January 2001 two of

[7] This information was obtained through a conversation with Dr Ahmed El-Diwany, dean of IGER in January 2001.



Phase One:

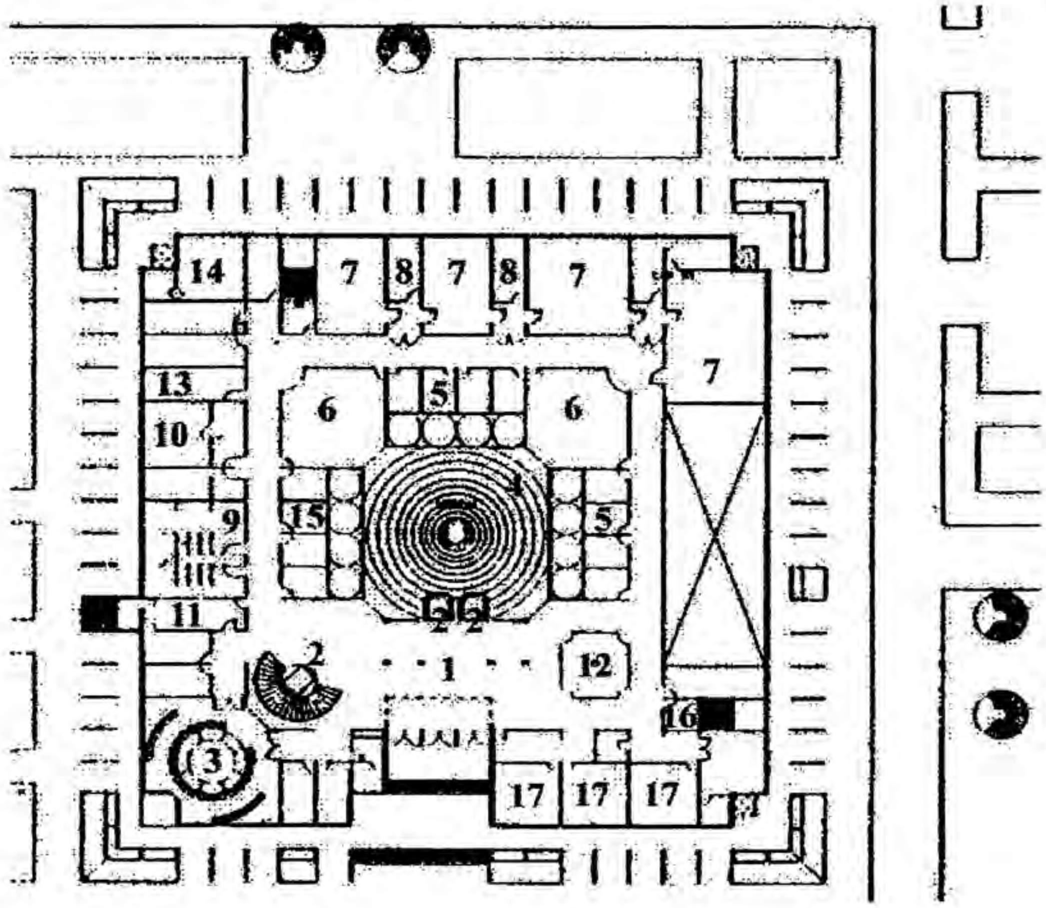
1) Institute for Genetic Engineering Research
2) Institute for New Materials and Advanced Technology
3) Institute for Informative Research

Phase Two:

4) Building for Celebrations
5) Stadium
6) Sports Centre
7) Area for further Research Centres
8) Recreational Centre
9) Staff Accommodation

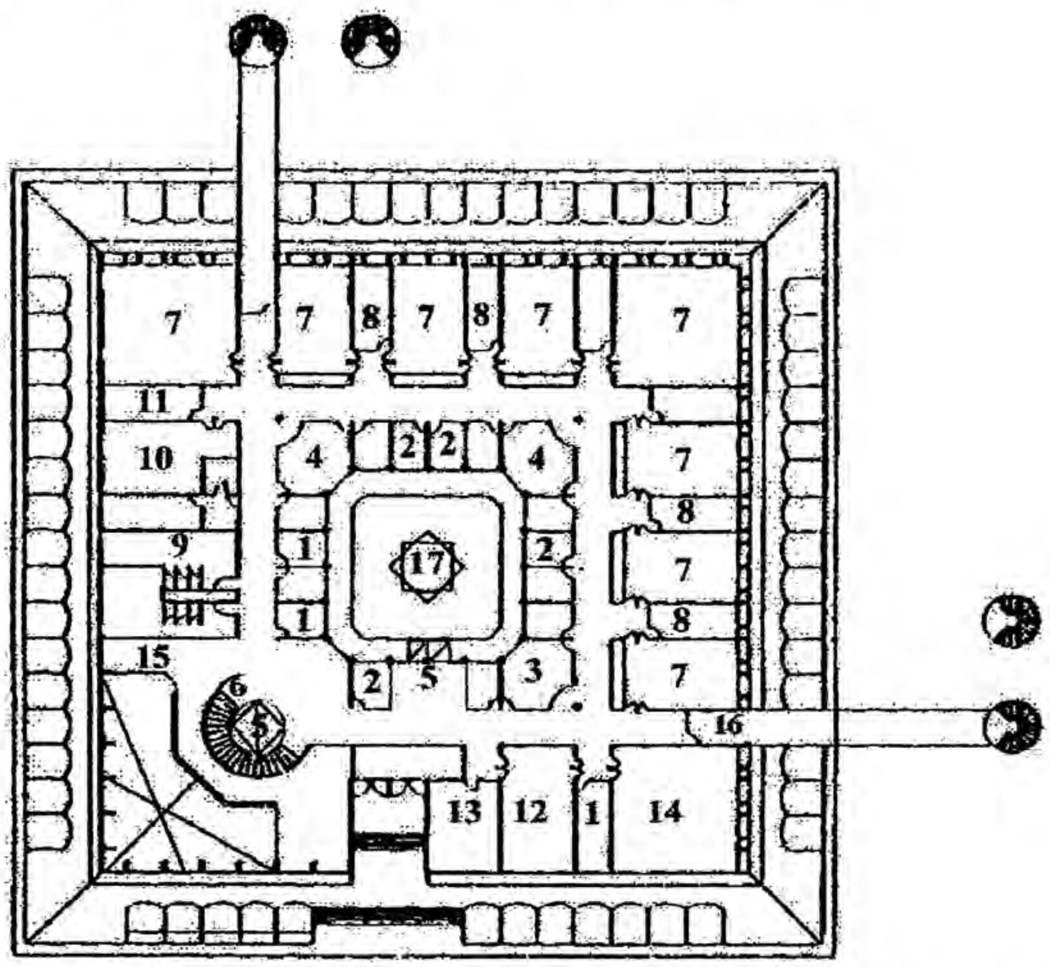
Figure 3.1.5.1 Site plan of Mubarak City for Scientific Research
Source: Medina Magazine, Special Issue on MCSR, December 1999

them where occupied with air conditioning services and only the central one served as a meeting room. Next to the lift lobby, there is a 'break out area'. It serves as a space where informal discussions can take place. The chairman's office and related rooms occupy this floor. This floor is chosen for spatial analysis. **Figure 3.1.5.6** represents the second floor of IGER. The plan gets considerably smaller in size as we go up the pyramid. On this floor, there are only laboratories with a couple of chairman rooms and the corridor overlooks the inner courtyard. **Figure 3.1.5.7** represents the third floor of IGER an L-shaped library occupies the right hand corner of the floor with a photocopy room adjacent to it and a smaller L-shaped computer hall occupies the left hand corner of the floor. There are six research rooms facing outwards.



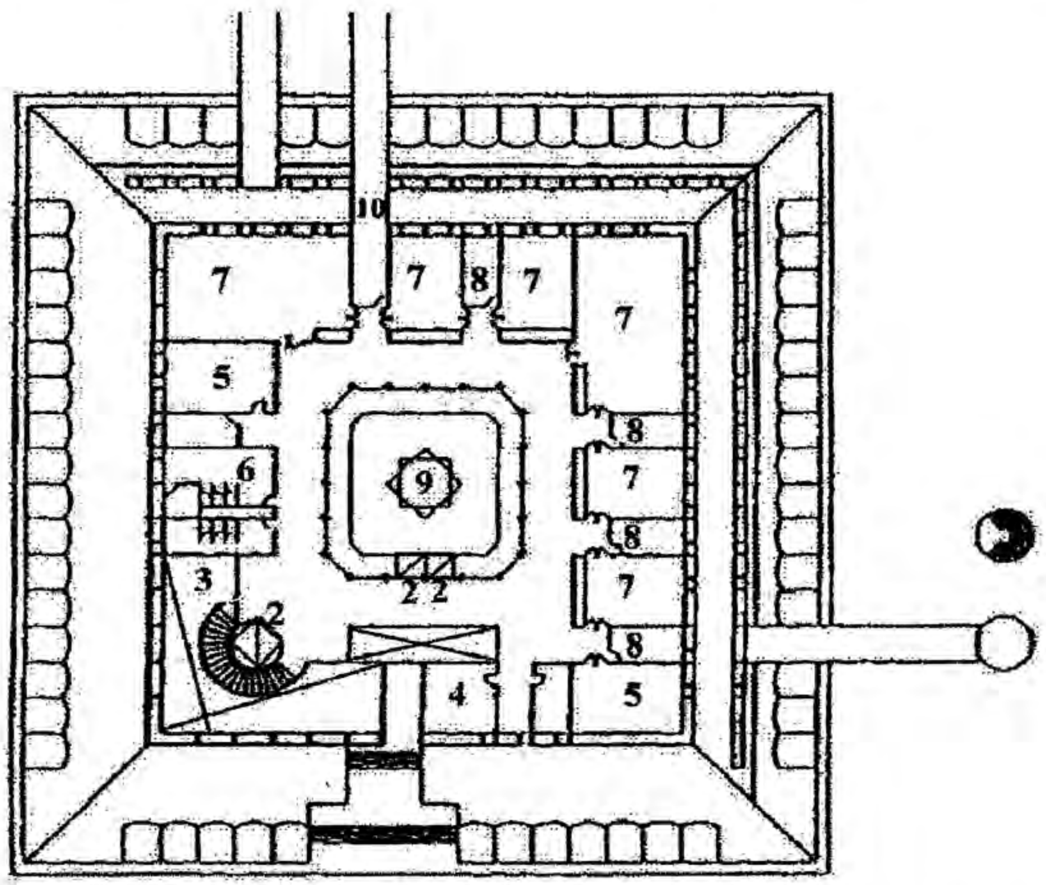
1 Entrance	2 Lift	3 Seminar room	4 Atrium
5 Research office	6 Meeting rooms	7 Laboratory	8 Preparation
9 Toilet	10 Cold room	11 Service	12 Waiting area
13 Dark room	14 Chairman	15 Secretary	16 Exit
17 Administration			

Figure 3.1.5.4 The ground floor of IGER
Source: Medina Magazine, Special Issue on MCSR, December 1999



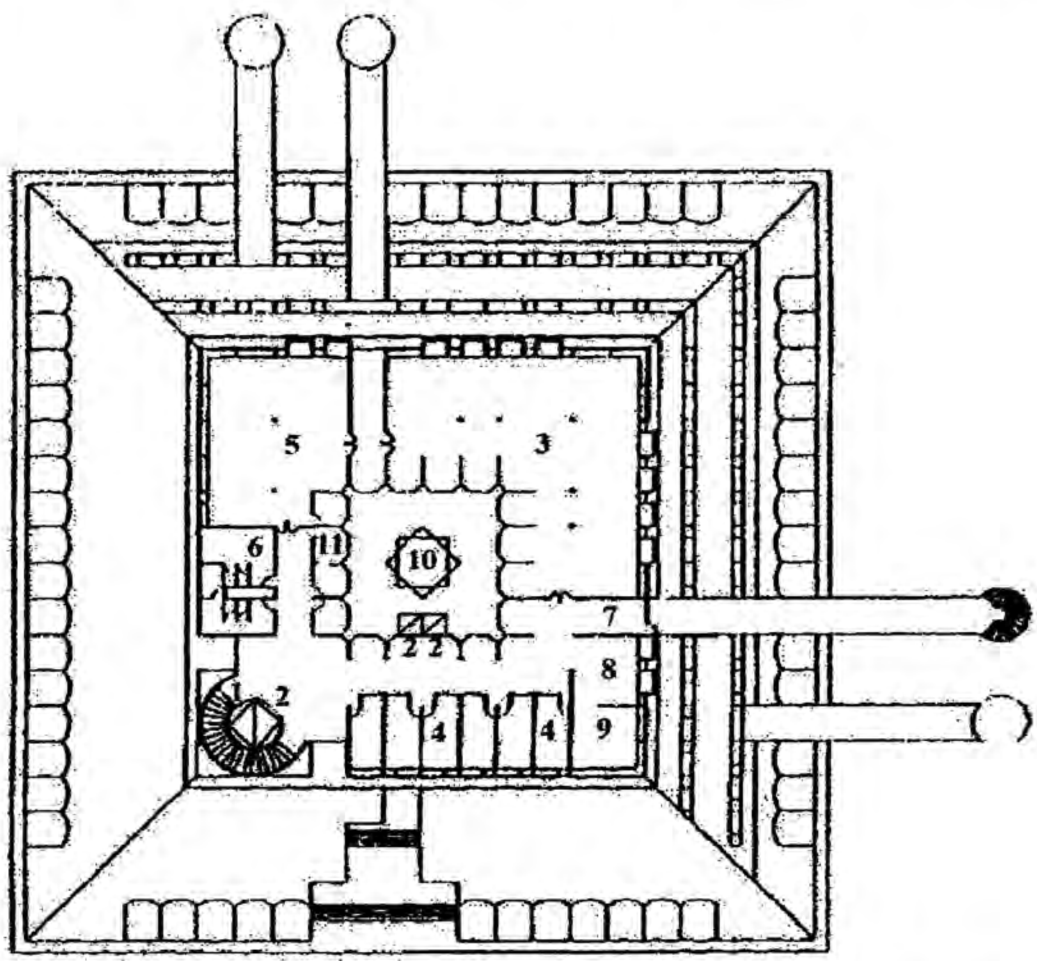
1 Secretary	2 Research Office	3 Seminar room	4 Meeting room
5 Lifts	6 Main stairs	7 Laboratory	8 Preparation room
9 Toilets	10 Cold room	11 Service	12 Dean
13 Waiting room	14 Board meeting room	15 Break out area	16 Exit
17 Atrium			

Figure 3.1.5.5 The first floor of IGER
Source: Medina Magazine, Special Issue on MCSR, December 1999



1 Main stairs	2 Lifts	3 Void	4 Meeting
5 Chairman	6 Toilet	7 Laboratory	8 Preparation room
9 Atrium	10 Exit		

Figure 3.1.5.6 The second floor of IGER
Source: Medina Magazine, Special Issue on MCSR, December 1999



1	Main Stairs	2	Lift	3	Library	4	Research office
5	Computer room	6	Toilet	7	Exit	8	Information office
9	Secretary	10	Atrium	11	Programmers		

Figure 3.1.5.7 The third floor of IGER
Source: Medina Magazine, Special Issue on MCSR, December 1999

Advantages of the design:

1) All spaces are well lit because of the atrium.
2) The whole building is relatively small which facilitates communication among inhabitants.
3) Visibility is allowed through the courtyard, which encourages social interaction and hence scientific interaction.
4) The presence of meeting rooms and informal meeting areas facilitate communication.

Disadvantages of the design:

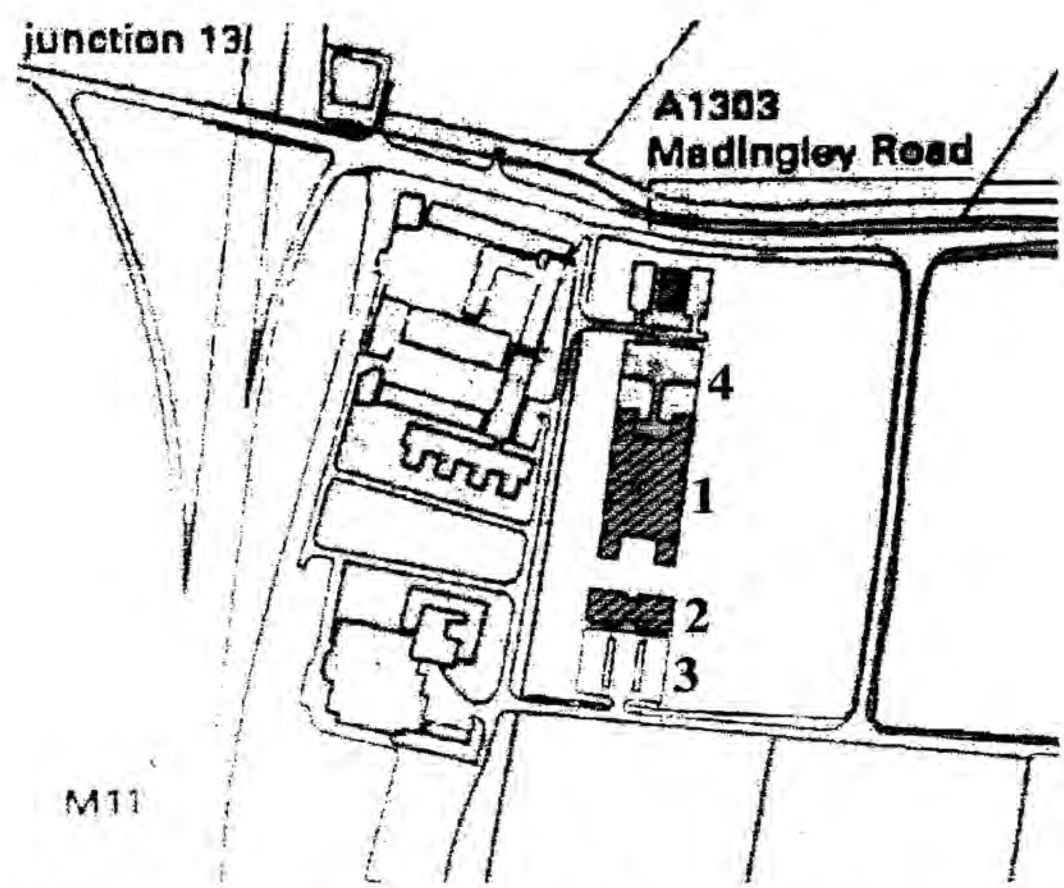
1) The three buildings are not linked, so communication is diminished among users of the three research centres.
2) The pyramid shaped form gives no chance of vertical extension of any of the three centres.
3) The lack of a dining room or a café especially as the centre is situated in an isolated place in the desert.
4) The lack of transportation to the site.
5) The present lack of accommodation for researchers decreases attendance as all inhabitants come from far away places across the country and they have to commute every day. This point should be covered when phase two of the project gets built.

3.1.6 Schlumberger Cambridge Research Centre, SCRC, Cambridge, UK, 1982

Located just outside Cambridge, the building designed by the British architect Michael Hopkins, is a centre for research into aspects of oil exploration, including drilling and fluid mechanics and computer modelling of drilling information. **Figure 3.1.6.1** is a site plan of the research centre. **Figures 3.1.6.2a-c** are different views of the building.

Figure 3.1.6.3 represents the single-storey plan of SCRC. The building consists of two wings placed 24 metres apart and in between them a drilling-rig testing station, a library and staff recreation space are placed. The two wings comprise laboratories, research offices, break out areas for informal discussions and toilets. Normally in a building of this kind, the dirty activities of the testing station would be placed well away from the other functions, but because the client was keen to promote communication among scientists in all departments including those working in the testing station, so Hopkins' solution was to put the testing station right in the heart of the building where it can be overlooked by all laboratories[8]. The laboratories are facing inwards overlooking the drilling courtyard. The staff recreation space is right in the heart of the building and it includes a café and a library as well as a main reception area (see **figures 3.1.6.2b&c**). The library and the café are acoustically insulated by laminated glass units. The research offices are facing outwards onto a green area (see **figure 3.1.6.2a**). Each wing is divided into five sections, articulated by recessed entrances. Entrances lead to

[8] Davies, C., *The Work of Michael Hopkins*, Phaidon Press Ltd, London, 1995, pp 59-63



1 Main building (Phase One)
2 Extension building (Phase Two)
3 Car parking
4 Service yard

Figure 3.1.6.1 Site plan of the Schlumberger Cambridge Research Centre
Source: Davies, C., *The Work of Michael Hopkins*, Phaidon Press Ltd, London, 1995, pp.59-63

break out areas where informal discussions between researchers can take place outside the research offices and the laboratories. **Figures 3.1.6.4a-c** are different sections of the centre. Services are mostly accommodated below floor level. The air-conditioned laboratories are provided with under crofts to house air-handling equipment and other plant, while electrical and data services are carried in the troughs of the steel-decked suspended floors.[9] This building was phase one of the SCRC and phase two was added few years later. As can be noticed from **figure 3.1.6.5**, the addition did not include another café or library so that scientists of the new building integrate with scientists working in the phase one building in the café and the library.

Advantages of the design:

1) The single storey research centre maintains maximum communication level among users.
2) Communication is maintained through the café which is right in the heart of the building and visible by all spaces.
3) The main entrance is integrated with the café which promotes communication among staff members.
4) The library is placed right in the heart of the building which promotes communication.

Disadvantages of the design:

1) The only disadvantage that can be mentioned about this research centre is that it is composed of two wings which divides users spatially but the opposite argument is that cross visibility is

[9] Davies, C., *The Work of Michael Hopkins*, Phaidon Press Ltd, London, 1995, pp 59-63.

maintained through the continuous use of glass and also the users of the two wings meet daily in the café.

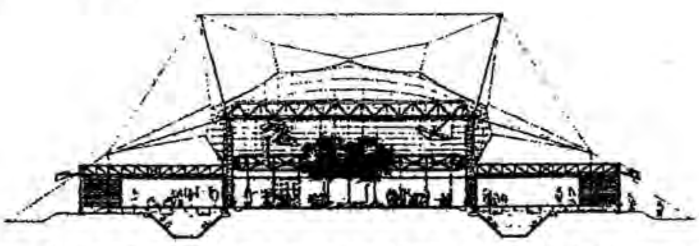


Figure 3.1.6.4a Transverse section through café, labs and offices.
Source: Davies, C., *The Work of Michael Hopkins*, Phaidon Press Ltd, London, 1995.

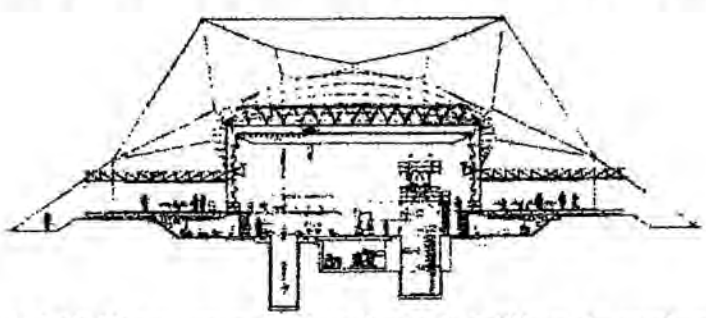


Figure 3.1.6.4b Transverse section through drilling rig station, labs and offices.
Source: Ibid.

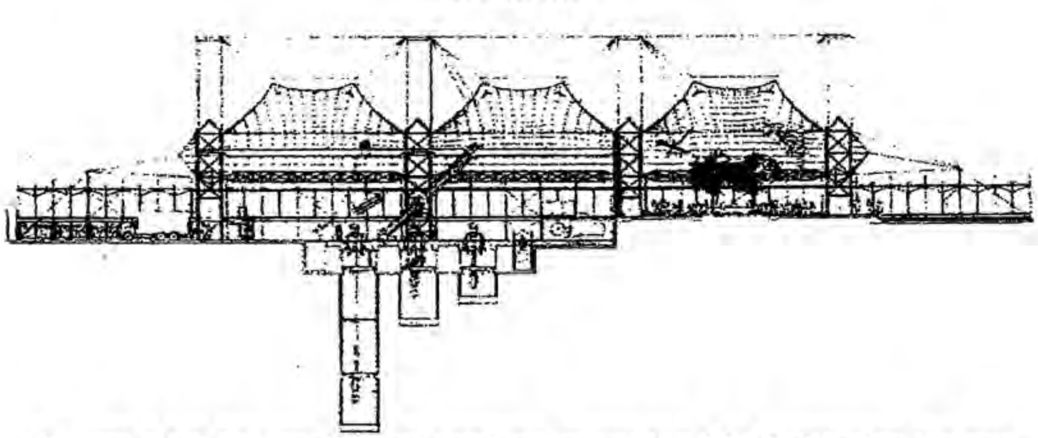
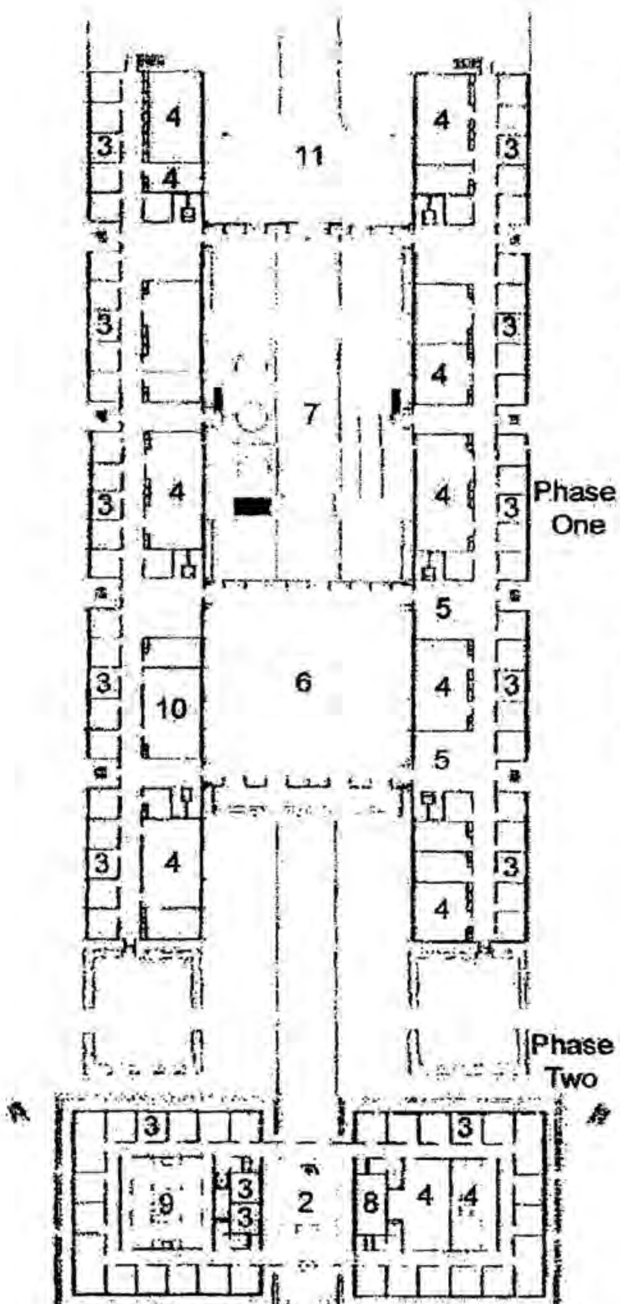


Figure 3.1.6.4c Longitudinal section through the SCRC showing the car parking, drilling rig test station and the café and entrance.
Source: Ibid.



1 Car parking
2 Entrance hall
3 Research office
4 Laboratories
5 Break out area
6 Café/ library
7 Test station
8 Meeting
9 Conference
10 Library
11 Service Yard

Figure 3.1.6.5 Phases One & Two of SCRC
Source: Davies, C., *The Work of Michael Hopkins*, Phaidon Press Ltd, London, 1995.

3.1.7 Camelia Botnar Laboratories, CBL, Great Ormond Street Hospital, London, UK, 1993

This building is an addition to the Great Ormond Street Hospital.[10] The five-storey building is a pathology laboratory. It is designed by DEGW architects and completed around 1996. Research inside the laboratory is based mainly on computer technology. **Figures 3.1.7.1 & 3.1.7.2** show a typical plan and a section of the building respectively. The floor plan is divided into three longitudinal sections with labs on the two peripheries facing outwards and a central section that contains lab support spaces, staircases and a coffee bar. Coffee bars located on each floor overlook a small sky lit atrium which provides daylight in the centre of the deep plan (see **figure 3.1.7.3**). A small meeting room is located in the heart of each floor. Stairwells are made of transparent glass. The two long span wings laboratories on either side of the plan are column-free for various combinations of laboratory and office. Services are located in risers 6.4m apart which contain electrical cables, piped services, consumer units and space for extract flues.

10 Griffin, Brian, Laboratory Design Guide, Architectural Press, 1998.p.133-135.

Advantages of the design:

1) The presence of a coffee bar overlooking the atrium close to the main lift on each floor facilitates visibility and communication among users.
2) The presence of a meeting room on each floor also facilitates communication.
3) The choice of transparent glass for stairwells improves visibility through the plan.
4) Daylight is brought into the deep plan through the sky lit atrium.
5) Column free long span laboratory units help achieve flexibility.

Disadvantages of the design:

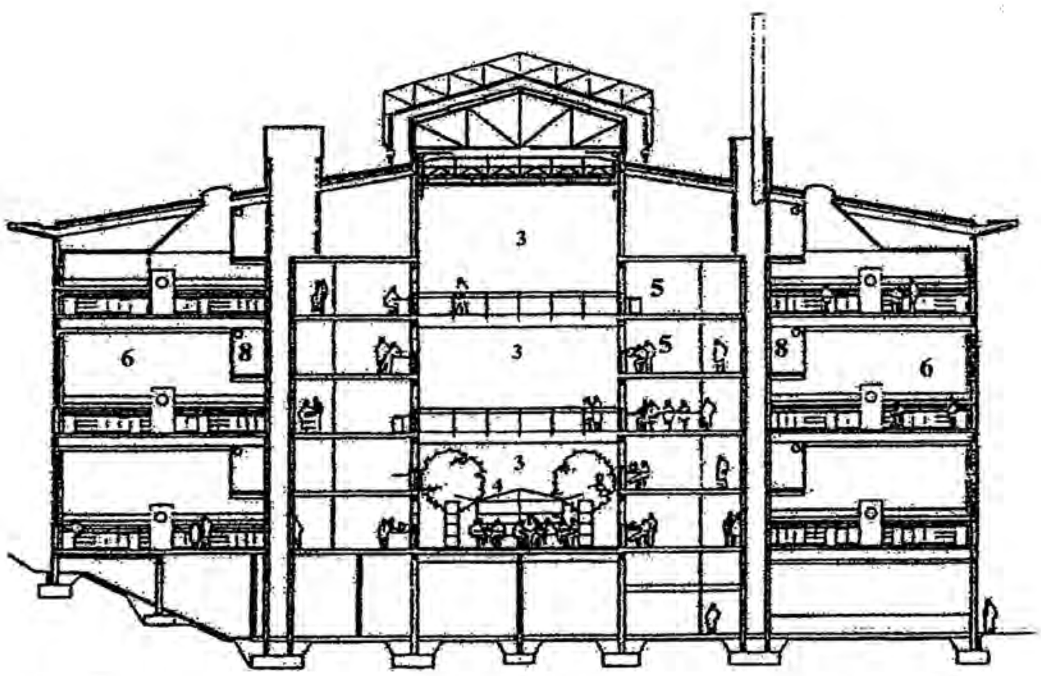
1) Some of the research offices lack natural light and ventilation.
2) Lab support spaces in the heart of the plan as well as the meeting room lack natural lighting and ventilation.
3) The absence of a café or restaurant to integrate all the inhabitants of the laboratory building.

3.1.8 Institute of Medical Sciences, IMS, University of Aberdeen, Scotland, UK, 1993

The client wanted a 'research hotel', where research teams might expand or contract as funding comes and goes.[11] This lead to the notion that different multi-discipline teams will have to justify their occupation of highly serviced laboratory space, and that they may occupy it for varying periods of time. As a result, the architect made flexibility the main priority of this building's brief. The institute is designed by the British Architectural Firm of David Murray Associates. **Figures 3.1.8.1a-c** are different views of the building. **Figures 3.1.8.2 &3.1.8.3** are the typical floor plan and the section of the building respectively. The design is based on double height laboratories interspersed with equipment rooms aligned along a corridor facing outwards. Across the corridor from the laboratories are the research offices facing a central sky lit atrium. As a result of this design, offices are doubled in number compared to the laboratories (see the section, **figure 3.1.8.3**). The upper corridor above the labs allows maintenance access to the services distributed along the galleries over the labs, without disturbing the work below.

The laboratories have a double height ceiling and are naturally lit. Users can alter the natural ventilation and lighting by closing blinds or opening lower windows, while a sophisticated building management system monitors and operates the upper windows and blinds.

[11] Griffin, Brian, Laboratory Design Guide, Architectural Press, 1998.



3 Atrium
6 Laboratory
4 Coffee room
8 Service corridor
5 Research Office

Figure 3.1.8.3 Section of IMS showing the double height laboratories and the service corridor on the upper floor of the lab. In the centre of the atrium the coffee room is visible.

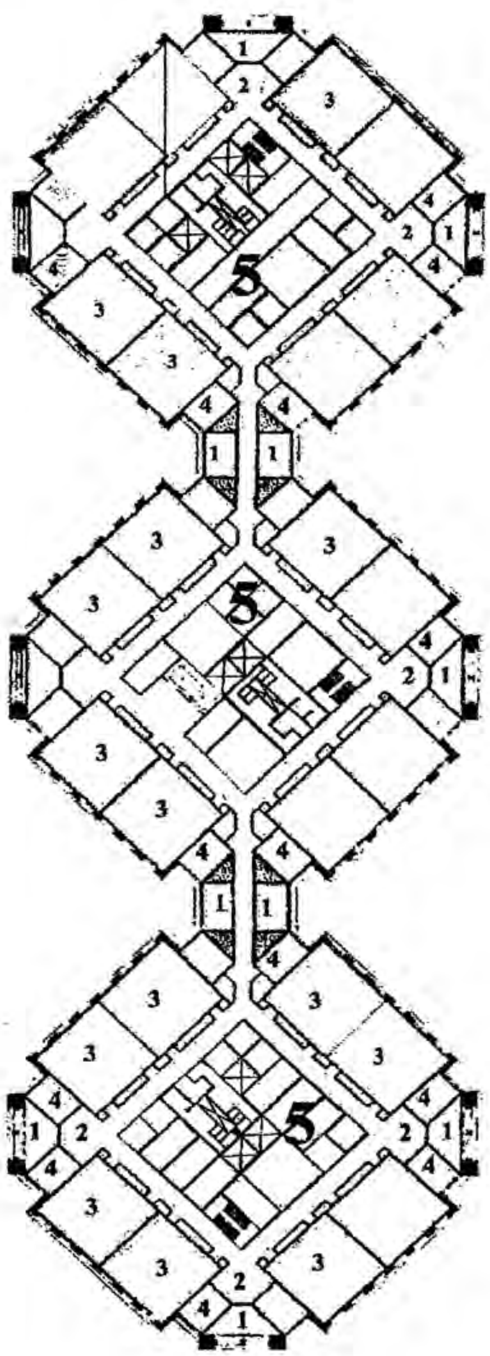
Source: Griffin, Brian, *Laboratory Design Guide*, Architectural Press, 1998. P. 139

The research offices are ventilated into the naturally ventilated atrium. The offices look across at one another over the 9.6m width of the atrium. The inhabitants can see the activity at the entrance level where next to the entrance, a photocopier room and a coffee room are located.[12]

Advantages of the design:

1) All floors are well lit.
2) Visibility is facilitated across the institute through the atrium.
3) The positioning of the coffee room on the ground floor only makes it the collective recreational space for all floors and the space where everybody meets.

12 Griffin, Brian, *Laboratory Design Guide*, Architectural Press, 1998.p.136-139.



1 Meeting room
2 Break out area
3 Laboratory
4 Research office
5 Lab support spaces

Figure 3.1.9.2 The second floor plan of BSC
Source: *Architecture Magazine*, March 1993. P. 125

3.1.10 Skirball Institute of Biomolecular Medicine, SIBM, New York University, New York City, USA, 1993

Inserted between two buildings on New York University's urban medical campus, the 23-storey building (see **figure 3.1.10.1a**) comprises an institutional and residential enclave. Designed by Polshek /Payette Associates, the institute occupies the lower 5-storeys of the building. Known as the Skirball Institute of Biomolecular Medicine, it comprises research laboratories and faculty offices, while the upper levels provide apartments for staff and medical offices. **Figures 3.1.10.1a-c** represent different views of the building.

Figure 3.1.10.2 represents a typical floor plan of the institute. A curved five-storey pavilion containing research administration, conference rooms and lounges connects the institute to Tisch Hospital, an adjacent hospital. An open staircase is placed in the heart of the pavilion and by alternating shared instrumentation and conference rooms between floors, scientists are invited to socialise within this public element. The laboratories are organised along a double loaded corridor. The lab module is divided into two parts by a secondary corridor- an aisle that runs continuously between adjacent labs- a primary well-lit part with a bench and desk and a secondary support part behind the corridor. There are only eight separate research offices in this plan. [14]

14 Soloman, Nancy. "Laboratory Innovations", *Architecture Magazine*, March 1993. P.126.

Advantages of the design:

1) There is an auditorium, meeting rooms, break out spaces and a lounge in the pavilion on each floor and scientists are invited to 'socialise' in this element. All this is to achieve social and hence scientific interaction among floor staff.
2) The pavilion break out area is close to the main building's lifts & stairs lobby which creates further communication among staff.
3) In this pavilion, there is no 'territorial' space i.e. space allocated to a certain department. Therefore the sharing of these facilities in the pavilion will encourage communication, all through the floor.
4) The break out spaces along the main corridor can be used for interaction as the corridor is not the only place for circulation so it is not expected to be very busy.
5) The secondary corridor between labs encourages further communication between adjacent departments and thus strengthens departmental communication. So movement is divided between the three corridors and depending on interaction between departments across each other from the main corridor, it might be expected to be quiet during working hours and only busy at lunch hour, arrival and leaving times. This information can only be made certain of by observation of the floor.

Disadvantages of the design:

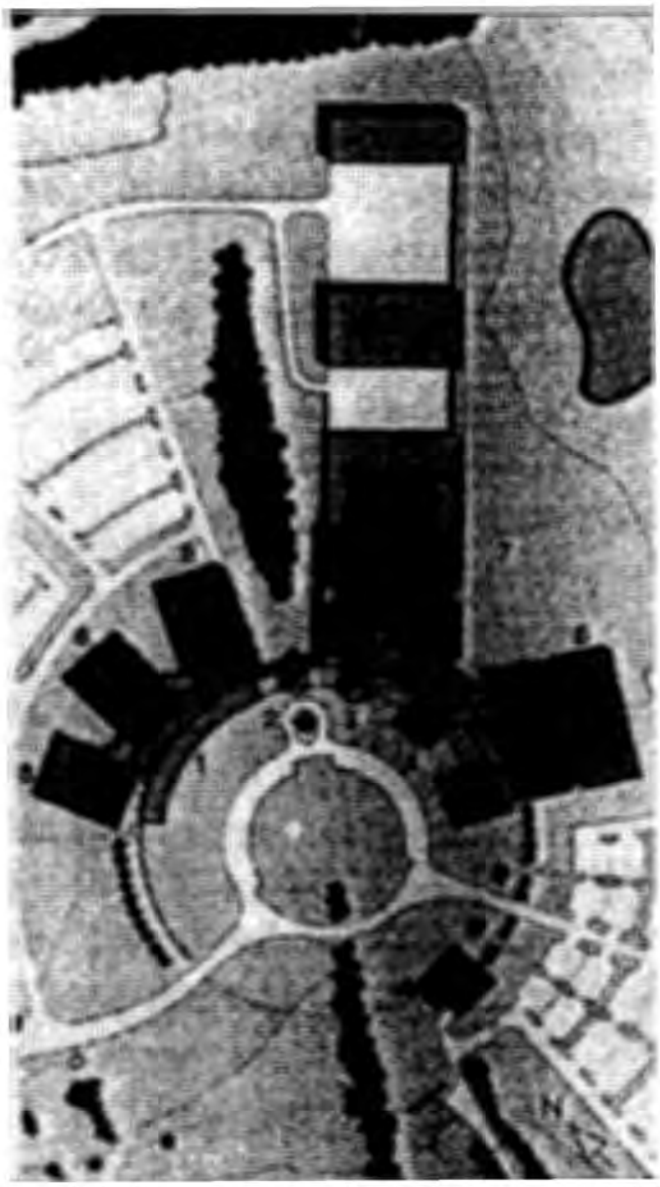
1) As the pavilion is 'stuck' to the building, it a *formal* communication space rather than an informal one. Scientists do not pass *by* the pavilion plan, they only go there if they have a meeting. This is different than break out areas where random and informal or serendipitous interaction can take place near the lab or office area.
2) Half the area of labs are not well lit, so sufficient artificial lighting has to be supplied.
3) The little number of research offices and the open lab plan makes privacy or quietness a sought after property in such a plan especially because the doorways between labs connect in the middle of the lab halfway between the main corridor and the end of the lab near the window. This could be a source of interruptions for the scientist who needs to have some privacy while writing up. Moreover, interaction takes place away from the natural movement in the main corridor. This could be compared to a study by Hillier and Penn where they argued that the spaces where adjacent labs open up to each other whether it is shallow in the lab i.e. near global movement in the main corridor or deep in the lab near the window end away from natural movement can have an effect on the quality of research produced as the passing by scientists in the former case can be encouraged to join in discussions while in the latter case are discouraged to join in conversation as they cannot overhear any part of the discussions. Thus interaction will remain at the department level.[15] (see ch.1, p.27)

[15] Hillier, B., and Penn, A., "Visible Colleges: Structure and Randomness in the Place of Discovery", *Science in Context* 4, 1.

3.11 Rhone-Poulenc Rorer US headquarters, RPR, Collegeville, Pennsylvania, USA, 1994

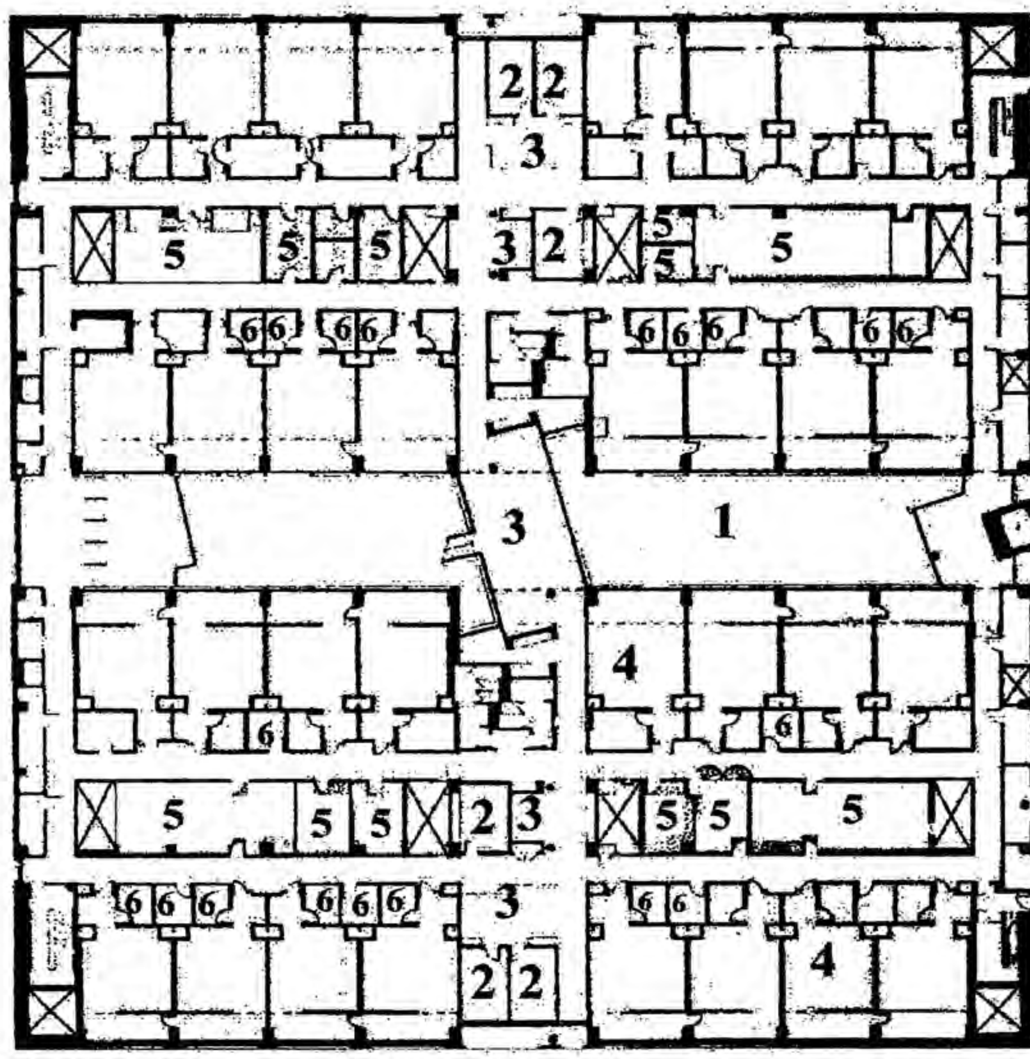
Rhone-Poulenc Rorer was formed in July 1991 as an alliance between the US-based Rorer group and the French pharmaceutical and chemical company Rhone-Poulenc. The new company quickly set out to assemble 2000 researchers, managers and support personnel, formerly located at dispersed sites, within a 100,000 square-metre headquarters.

The client requested the combination of the corporation's scientific, business and marketing divisions. CUH2A architects designed the US Research and Development Centre and Administrative offices as a series of laboratory and office pavilions linked by a curved circulation spine. **Figure 3.1.11.1** represents the site plan of the headquarters. The connecting zone includes common functions such as the library, auditorium and fitness centre. The architects provided opportunities for casual interaction both within hallways in the spine and between labs in the lab block. **Figures 3.1.11.2a&b** show an aerial view of the headquarters and the curved circulation spine. **Figure 3.1.11.3** represents the typical floor plan of the chemistry building which is the lab-based building under study (building number 6 in **figure 3.11.1**). **Figures 3.11.2c-f** represent different views of the chemistry building. It is an overall square plan consisting of two building blocks covered by one roof and joined by three links on all floors and separated by a longitudinal sky lit atrium (see **figure 3.1.11.2f**). Each block is divided into 3 parts with two corridors between them. The labs are at the perimeter, half of them facing outwards and the other half facing the atrium (see **figure 3.1.11.2d**).



1	Fitness Centre	2	Lobby	3	Auditorium	4	Library
5	Dining	6	Chemistry building	7	Biology Building	8	Corporate Office

Figure 3.1.11.1 Site Plan of Rhone Poulenc Rorer Research Centre
Source: Soloman, Nancy. "Laboratory Innovations", *Architecture Magazine*, March 1993, p.124.



1 Atrium 2 Meeting room 3 Break out area
4 Laboratory 5 Lab support spaces 6 Research office

Figure 3.1.11.3 The typical floor plan of the chemistry building of RPRRC
Source: Soloman, Nancy, "Laboratory Innovations", *Architecture Magazine*, March 1993, p.124.

The offices are on the corridor but in this case artificially lit and ventilated. In the centre of each section is a longitudinal part of lab support area also artificially lit and ventilated. The ground floor comprises a café which serves occasionally as a large meeting area for the whole company (**figure 3.1.11.2c**).

Advantages of the design:

1) The global linking of all buildings of the headquarters through the curved central spine.
2) The chemistry building is all well lit through the atrium.
3) The continuous linking on each floor of the two parts of the lab-based chemistry building (see **figure 3.1.11.3**).
4) The presence of break out areas on each floor in the way of natural movement (see **figure 3.1.11.3**).
5) The presence of conference/meeting rooms on each floor in the way of natural movement (see **figure 3.1.11.3**).
6) The doorways between labs strengthen departmental interactions.

Disadvantages of the design:

1) The repetition of the plan and linking it gives no need for inhabitants of one part of the floor to cross to the other part as they have the exact same facilities.
2) The shift of axis between the two corridors leading to the central link in the heart of the plan weakens visibility and thus permeability between the two sections of the building.
3) Research offices are artificially lit and ventilated and simply are rooms with no windows.

3.1.12 Kazusa DNA Research Institute, KDNARI, Kisarazu city, Chiba, Japan, 1994

This is one of the main facilities in Kazusa Academic Park, which Chiba Prefecture is developing it into a state of the art research centre for advanced technology. It specialises in the analysis of DNA structure. **Figure 3.1.12.1** represents the site plan of the institute. The institute consists of the following four interconnected buildings: The general facilities building (building no 1), the central building (building no 2), the west wing laboratory building (building no 3) and the east wing laboratory building (building no 4). The institute is surrounded by a huge green area. It is designed by the Japanese architectural firm Nikken Sekkei Ltd. The request of the client was to separate the laboratories and research offices from the rest of the facilities in order to "create a spatial organisation conductive to communication among researchers to work without interruption"[16]. And so was the design solution. The design separated 'work' from recreational facilities by creating a four-storey building for labs, offices, conference, meeting purposes and a single storey building for general purposes and linked the two buildings through a bridge that connects them through the second floor as can be seen in the section (see **figure 3.1.12.4**)

Figures 3.1.12.2a-k represent different views of the exterior and interior of the institute. **Figures 3.1.12.3 & 3.1.12.5** represent the second and first floor plans of the institute respectively. The plan is triangular in shape with a round corner (the central building) with two sides of labs and offices (the two

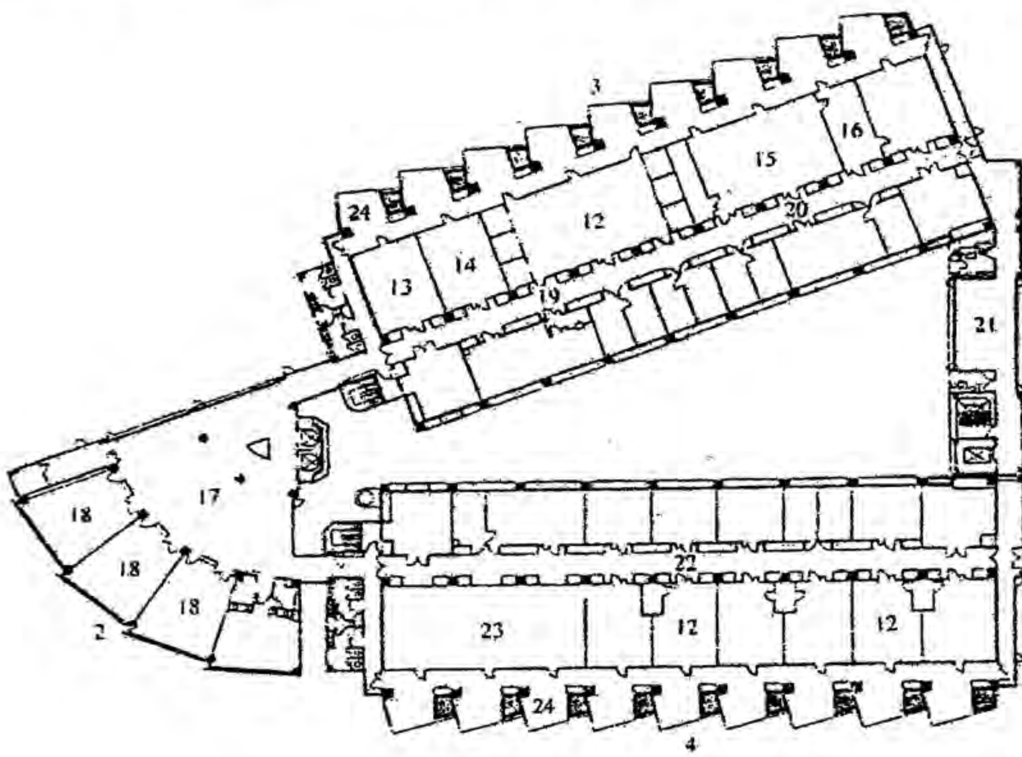
16 Laboratories & Research Facilities, New Concepts in Architecture & Design, Meisei Publications, 1996. P.176

laboratory wings). The labs open onto the central corridor, which houses the research offices. The round corner of the plan contains seminar rooms. The base of the triangle comprises a coffee area next to the lifts and staircases. The set of labs facing the courtyard overlook other labs through it, while the other set of labs on the other side of the corridor open onto a back corridor where each lab has a little lounge serving as a research office or break out area with a view of the park (see **figure 3.1.12.2c**). **Figure 3.1.12.4** represents a section of the institute which shows the bridge linking the single floor of the general facilities building to the second floor of the central building. This is shown in the second floor plan (see **figure 3.1.12.5)**[17].

Similar to the Skirball Institute of Biomolecular Medicine, SIBM[18], this research institute has a slightly separate part (the central building) for meeting and seminar rooms, and a further separate part (the general facilities building) for administration & guest rooms. Unlike the SIBM it is in the way of circulation between the two lab wings and main lifts are placed in it so it encourages natural movement to pass by it. Researchers working in different laboratory wings can interact in the lobby of the central building (see **figure 3.1.12.2e**) or in the main lounge on the other side of the building (see **figure 3.1.12.2k**) or in the back corridor behind their labs. They can sit and talk quietly in the little break out spaces or lounges which can also be used as quiet writing down spaces.

[17] Laboratories & Research Facilities, New Concepts in Architecture & Design, Meisei Publications, 1996, p.168-176.

[18] see page 23



2	Central building	17	Lift lobby
3	West wing laboratory building	18	Seminar room
4	East wing laboratory building	19	Lab of DNA technology
12	Laboratory	20	Lab of genome function
13	DNA synthesis room	21	Lounge
14	DNA analysis room	22	DNA sequencing laboratory
15	Terminal equipment room	23	DNA sequencer room
16	Computer room	24	Break out area/ Lounge

Figure 3.1.12.5 The first floor of KDNARI
Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, 1996, Meisei Publications, p.175

Advantages of the design:

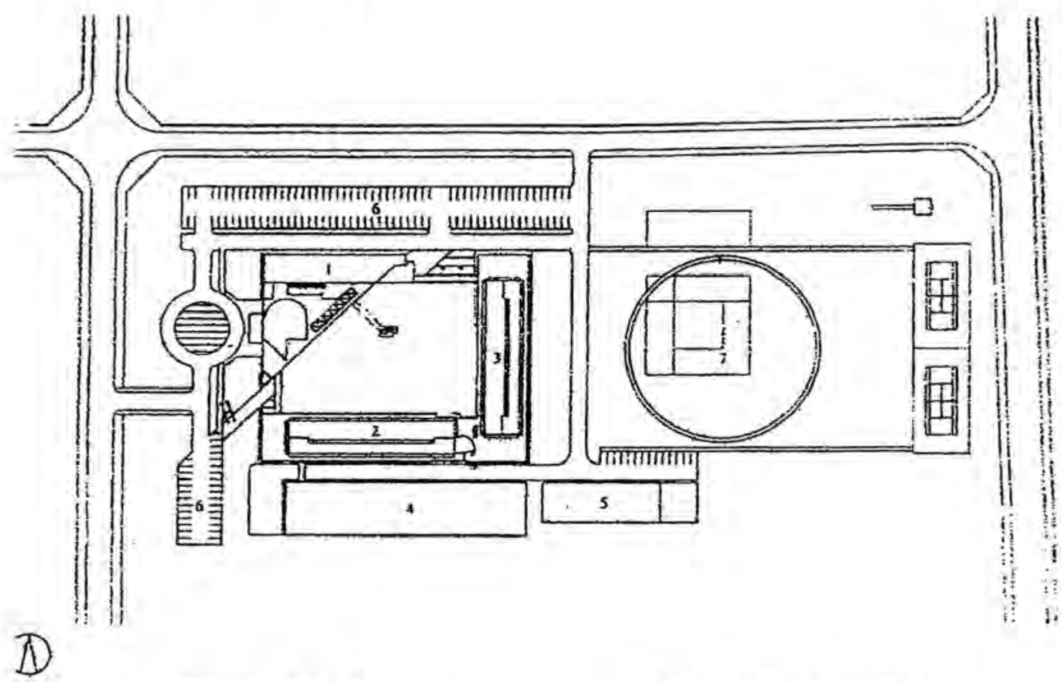
1) Labs facing the courtyard are well lit.
2) All labs lie on the main corridor.
3) The presence of a spacious lobby and meeting rooms in the central building and a lounge serving the two lab wings facilitates and encourages interaction and communication among staff and in this space scientists from the east and west wings can meet.

Disadvantages of the design:

1) Back labs do not have any view or natural ventilation as they open onto a back corridor.

3.1.13 Sandoz Tsukuba Research Centre, STRC, Tsukuba city, Ibaraki, Japan

Designed by the Japanese architectural firm Maki and Associates, this medical research centre is organised around a courtyard. **Figure 3.1.13.1** represents the site plan of the centre.

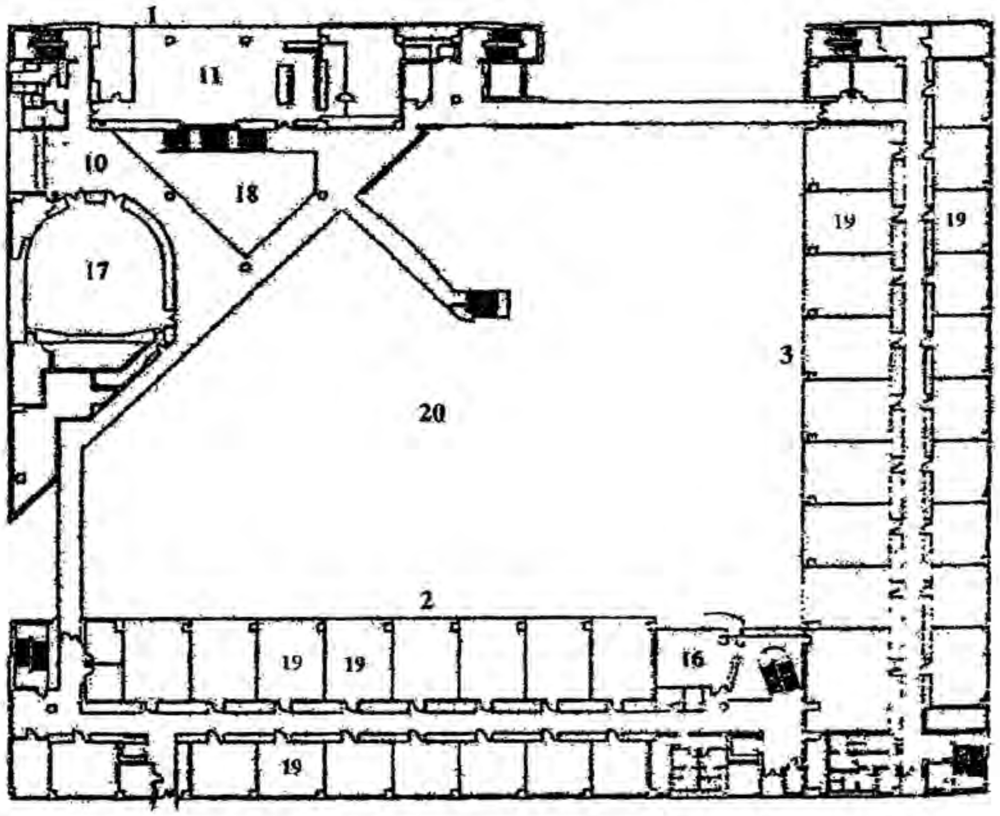


1 General Facilities Building
2 Research Laboratories I
3 Research Laboratories II
4 Biomedical Research Laboratories
5 Electrical Energy Supply Building
6 Parking area
7 Athletic Grounds

Figure 3.1.13.1 Site plan of Sandoz Tsukuba Research Centre
Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, 1996, Meisei Publications, p.177

Like the previous research centre, the designer decided to separate work from general purposes. A triangular-shaped building houses the general facilities while an L-shaped building comprises the laboratory wings. The centre is entered from the main entrance in the general facilities building on the ground floor (see **figure 3.1.13.2b**) or a side staff entrance and both entrances lead through lifts & staircases to the first floor of the general facilities building and through the two links to the laboratories on the first floor and through lifts or staircases to the ground floor laboratory wing. This very indirect approach to the ground floor laboratories can be explained by the classification of the work done in the ground floor laboratories. Also the two wings of the first floor laboratory wings are not connected but each is connected to the general facilities building while on the ground floor plan the two lab wings are connected to each other. The two buildings are linked on the first floor by long links (see **figures 3.1.13.2c&d**). **Figures 3.1.13.2a-h** are different views of the centre. **Figures 3.1.13.3 & 3.1.13.4** represent the ground and first floor plans of the centre respectively. **Figure 3.1.13.5** is an elevation of the research centre. On the ground floor of the general facilities building there is an entrance lobby (see **figure 3.1.13.2d&e**), a café (see **figure 3.1.13.2d**), a conference room (see **figure 3.1.13.2j**) and some administration rooms. On the first floor there is a foyer, an auditorium (see **figure 3.1.13.2f**) and a staff restaurant (see **figure 3.1.13.2h**). The laboratories overlook the courtyard while research offices of one wing overlook the athletic grounds of the research centre and the other wing overlooks another laboratory building (see **figure 3.1.13.1**). There is a lounge on the ground and first floor next to the main staircase[19].

[19] Laboratories & Research Facilities, New Concepts in Architecture & Design, 1996, Meisei Publications, pp. 177-184.



1	Administration building	16	Lounge
2	Research laboratories I	17	Auditorium
3	Research laboratories II	18	Void
10	Foyer	19	Laboratory
11	Staff Restaurant	20	Courtyard

Figure 3.1.13.4 The first floor of STRC

Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, 1996, Meisei Publications, p.182

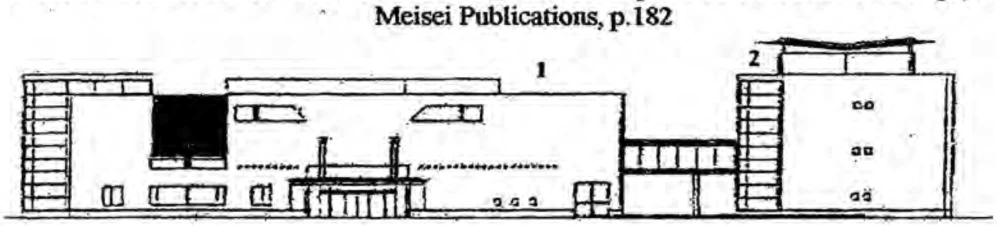


Figure 3.1.13.5 Elevation of the STRC showing the bridge linking between the first floors of the general facilities building and research laboratory wing II

Source: Ibid.

Advantages of the design:

1) All plan is well lit.
2) The presence of a café, foyer, restaurant, conference room and auditorium in the general facilities building facilitate meetings among researchers from the whole centre and thus discouraging territorial behaviour in favour of collective use of facilities.
3) The presence of a lounge on the ground floor serving both laboratory wings, facilitate communication among scientists working in the two wings.

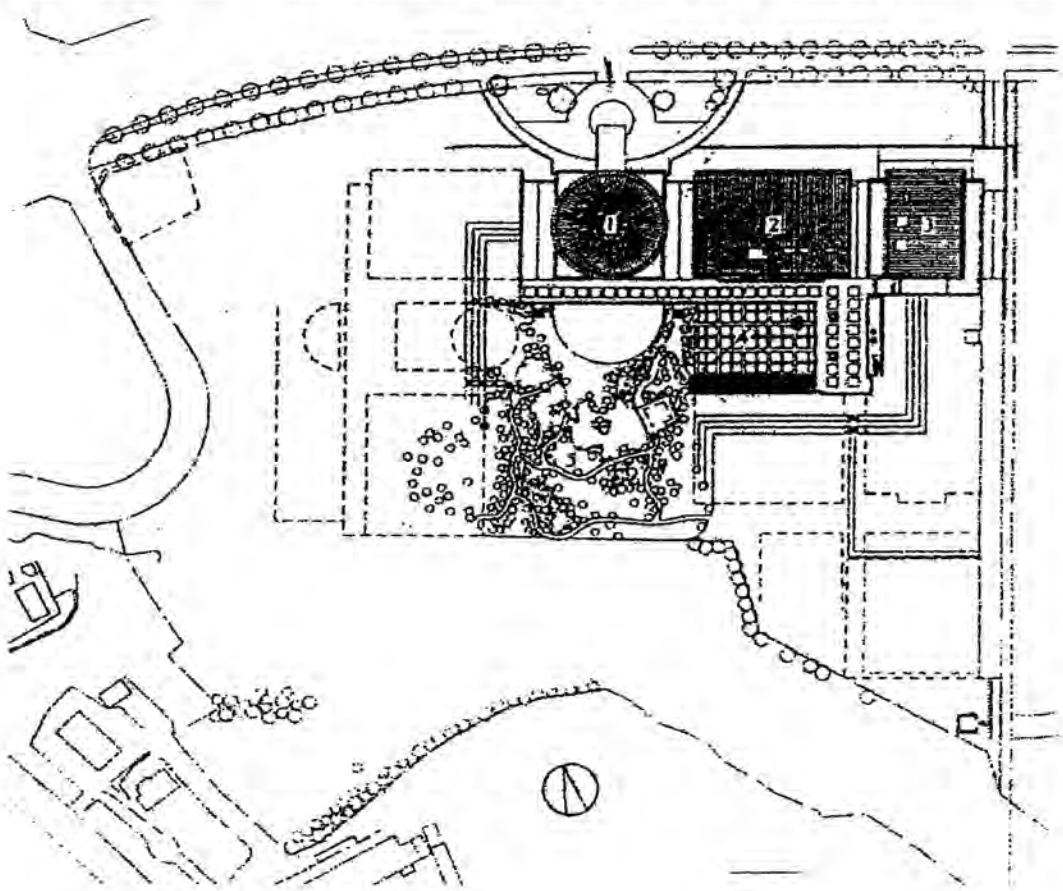
Disadvantages of the design:

1) The disconnection of the first floor of the two laboratory wings denies the staff of one of the wings to use the lounge on the first floor.
2) A meeting room serving the two laboratory wings could have been useful in order to facilitate meetings besides using the conference room in the general facilities building as one conference room is scarce for the whole centre. Advance booking of such a room would be expected to be a necessity.

3.1.14 Bayer Yakuhin Research Centre, BYRC, Kizu Town, Kyoto, Japan

Designed by the Japanese architect Kisho Kurokawa[20], this facility is the third general pharmaceutical research centre to be built by Bayer, after the ones in Germany and the USA. **Figure 3.1.14.1** represents the site plan of the centre. The centre comprises three separate buildings. The administration and general facilities building (building number 1), the biological research building (building number 2) and the pharmacological research building (building number 3). Facing the three buildings are a courtyard and a Japanese garden.

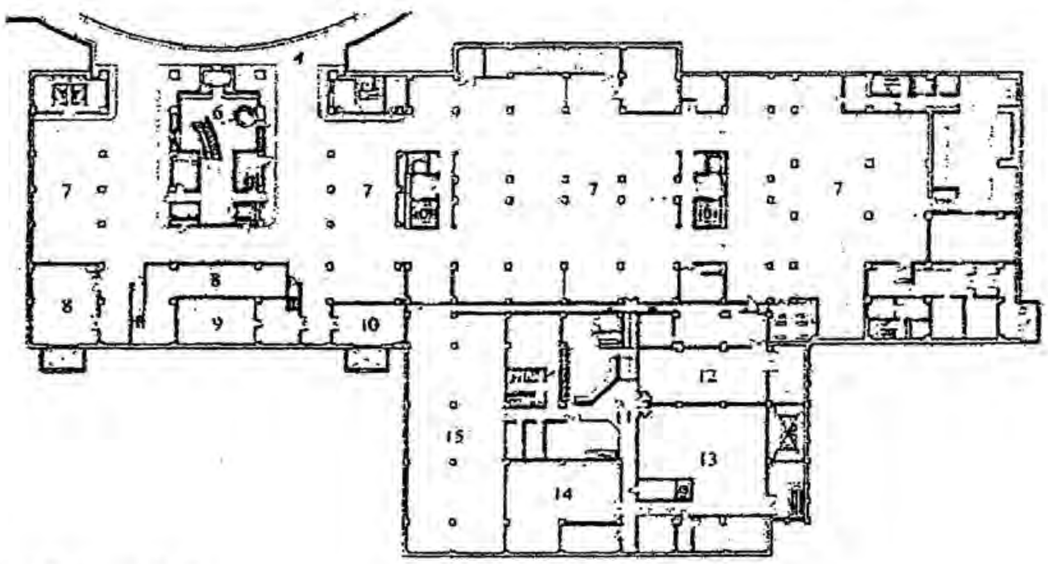
[20] Although this building is designed by a prominent architect 'Kisho Kirokawa', it is curious that he never refers to it in his CV, either on the internet or in any of the literature written about his work. The researcher made a thorough search for this building on the internet but to no avail. It seems it is not one of Kirokawa's better buildings.



1	General Facilities Building
2	Biological research building
3	Pharmacology research building
4	Courtyard
5	Japanese garden

Figure 3.1.14.1 Site plan of Bayer Yakuhin Research Centre
Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, Meisei Publications, 1996, p.185

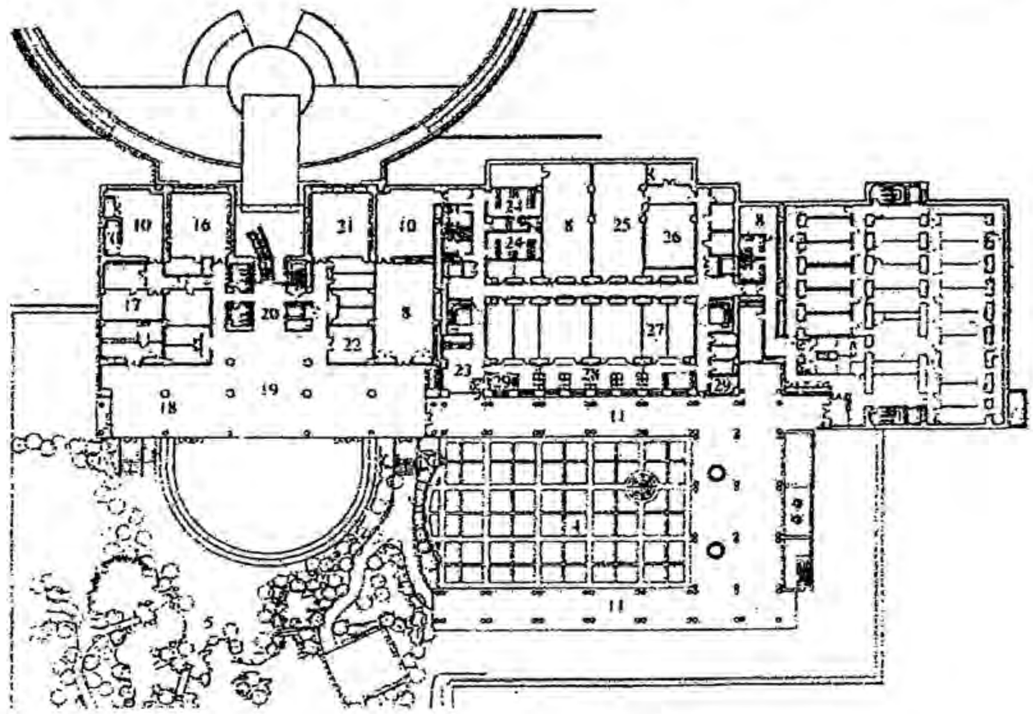
Figures 3.1.14.2a-g represent different views of the research centre. **Figures 3.1.14.3** represents the basement floor of the centre. The three buildings form one big car parking space and services. **Figure 3.1.14.4** represents the ground



6	Entrance hall	11	Corridor
7	Parking area	12	Generator room
8	Storage	13	Boiler room
9	Squash court	14	City water receiving tank room
10	Machine room	15	Electric room

Figure 3.1.14.3 Basement floor of BYRC

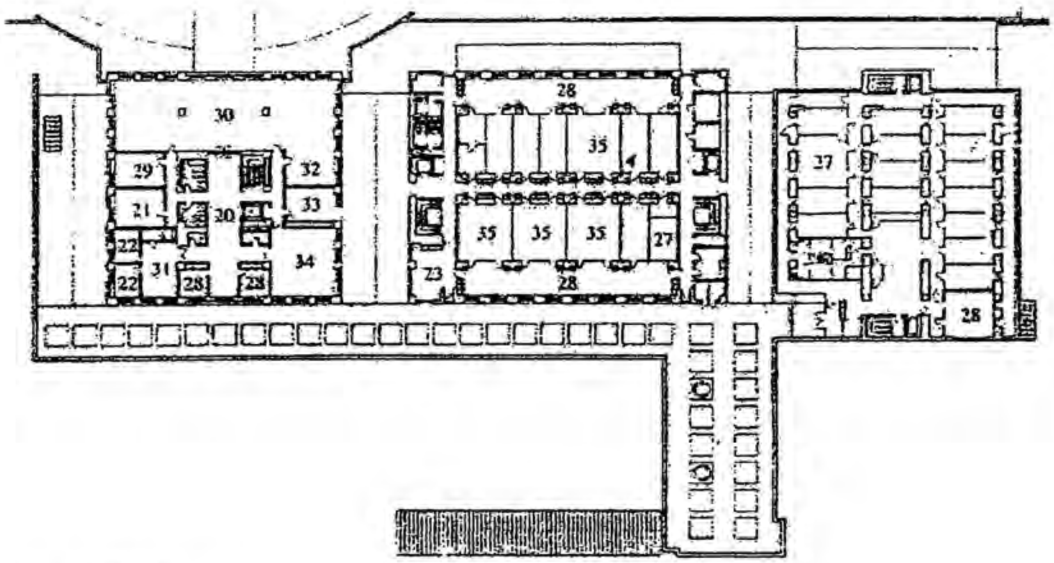
Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, Meisei Publications, 1996, p.188



4	Courtyard	20	Lift lobby
5	Japanese garden	21	Training room
8	Storage	22	Guest room
10	Machine room	23	Refreshment room
11	Corridor	24	Locker room
16	Administration office	25	Electrical mechanical room
17	Computer room	26	Plumbing mechanical room
18	Canteen area	27	Laboratory
19	Break out area	28	Office
		29	Meeting room

Figure 3.1.14.4 Ground floor of BYRC

Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, 1996, Meisei Publications, p.188



20	Lift lobby	30	Library
21	Training room	31	Lobby
22	Guest room	32	Scientific information room
23	Coffee room	33	Telecommunication room
27	Laboratory	34	Conference room
28	Office	35	Research room
29	Meeting room		

Figure 3.1.14.5 First floor plan of BYRC
Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, 1996, Meisei Publications, p.189

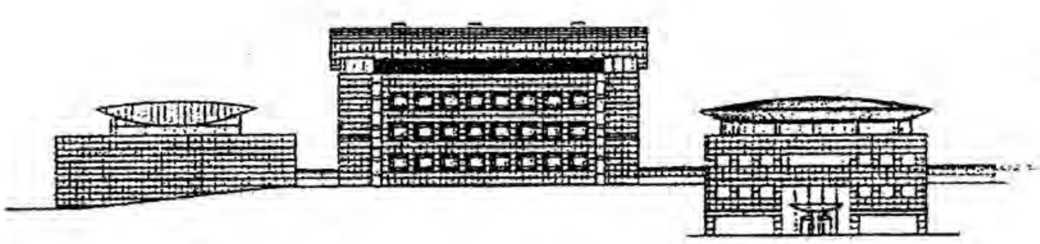
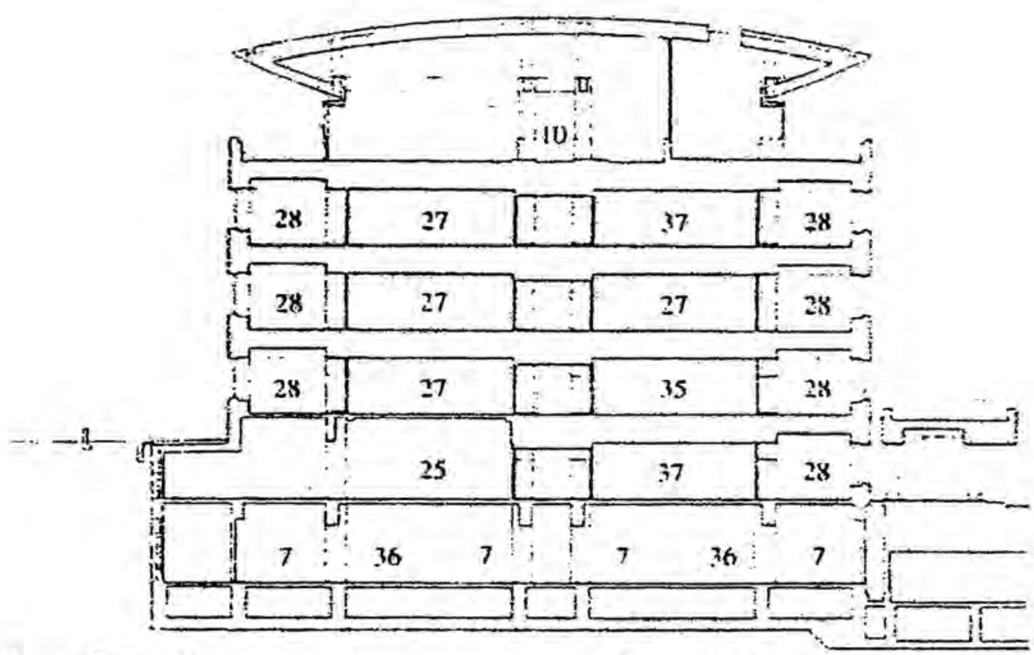


Figure 3.1.14.6 Elevation of BYRC
Source: Ibid



7	Car parking	28	Office
10	Corridor	35	Research room
25	Electrical mechanical room	36	Driveway
27	Laboratory	37	Preparation room

Figure 3.1.14.7 Section of the biological research building of the BYRC
Source: Laboratories & Research Facilities, New Concepts in Architecture & Design, 1996, Meisei Publications, p.190

Advantages of the design:

1) An architecturally pleasing building from the exterior and the quality of materials in the interior.
2) The presence of meeting rooms on the ground floor and lounges on other floors facilitate meetings among staff.

Disadvantages of the design:

1) There are no lounges in building number 3 so its users are supposed to use lounges in building number 1 or the café in building number 2.
2) As building number 3 is lacking in facilities like meeting and coffee rooms, it should have been placed next to building number 1, or building number 1 should have been placed in the middle between the two buildings, or a triangular relationship of permeability should have been established among the three buildings, where every building could be approached from the other two buildings without a building being farther than the other to the general facilities.

3.2 Comparative Analyses:

Having architecturally reviewed the 14 research centres, now some comparisons and conclusions need to be made. **Tables 3.2 a-d** summarise the advantages and disadvantages of the different research centres.

Table 3.2 a Advantages and Disadvantages of the Architectural Design

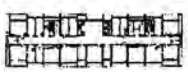
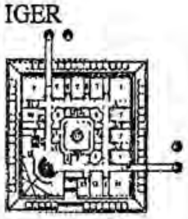
Research Centre	Advantages of Design	Disadvantages of Design
NRC 	1) Low rise building. 2) Break out areas open up onto the main circulation area (corridor) which facilitate interaction between scientists that are ready for interaction and passers by. 3) Research offices are located beyond labs so that visitors or fellow researchers have to pass through labs before reaching the offices and thus invade privacy of laboratory.	1) Very long mirrored plan. 2) The lack of meeting rooms, break out areas, cafés or any similar function.
HBRC 	1) All parts of the building are well lit. 2) Communication among researchers is well maintained in the left part of the building where the labs open onto and overlook the courtyard laboratory hall. 3) The one corridor based typical floor plan facilitates random interaction among researchers working in the same floor.	1) Lack of meeting rooms and break out areas. 2) Lack of coffee rooms on every floor.
GIF 	1) The limitation of height to one or two storey building facilitates communication.	1) Because all buildings in the site are not linked, communication among researchers from different buildings diminishes. 2) The distance between the two sets of labs south and north of the facility decreases communication between researchers working in each of them, especially the south building, it encounters very natural movement as it is away from administration and isolated from all natural movement. 3) Lack of meeting rooms, break out areas, café, coffee rooms or any collective activities space at the level of the GIF or at the level of the whole site.
NCNSRC 	1) The one corridor plan facilitates interaction between researchers on the same floor. 2) The presence of a library on the second floor.	1) Lack of meeting rooms and break out areas. 2) Lack of coffee breaks on every floor. 3) Lack of any informal collective space to house all users of the building, where people can interact informally. 4) The presence of services like photocopying machines and toilets in every department encourages interdepartmental communication but discourages communication outside the department. There is no reason for any person to walk outside the area of his/her department. It might be thought as efficiency but this reduces communication among users of floor and users of whole building. 5) The eight-storey building hinders communication among users of different floors as adjacency is lost for users of the eight floors.
IGER 	1) All spaces are well lit because of the sky lit atrium. 2) The whole building is relatively small which facilitates communication among inhabitants. 3) Visibility is allowed through the courtyard, which encourages social interaction and hence scientific interaction. 4) The presence of meeting rooms and informal meeting areas facilitate communication.	1) The three buildings are not linked, so communication is diminished among users of the three research centres. 2) The pyramid shaped form gives no chance of vertical extension of any of the three centres. 3) The lack of a dining room or a café especially as the centre is situated in an isolated place in the desert. 4) The lack of transportation to the site. 5) The present lack of accommodation for researchers decreases attendance as all inhabitants come from far away places across the country and they have to commute every day.

Table 3.2b Advantages and Disadvantages of the Architectural Design

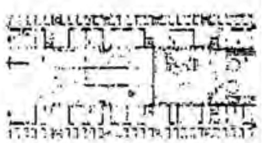
Research Centre	Advantages Of Design	Disadvantages of Design
SCRC 	1) The single storey research centre maintains maximum communication level among users. 2) Communication is maintained through the café which is right in the heart of the building and visible by all spaces. 3) The main entrance is integrated with the café which promotes communication among staff members. 4) The library is placed right in the heart of the building which promotes communication.	1) The only disadvantage that can be mentioned about this research centre is that it is composed of two wings which divides users spatially but the opposite argument is that cross visibility is maintained through the continuous use of glass and also the users of the two wings meet daily in the café.
CBL 	1) The presence of a coffee bar overlooking the atrium close to the main lift on each floor facilitates visibility and communication among users. 2) The presence of a meeting room on each floor also facilitates communication. 3) The choice of transparent glass for stairwells improves visibility through the plan. 4) Daylight is brought into the deep plan through the sky lit atrium. 5) Column free long span laboratory units help achieve flexibility.	1) Some of the research offices lack natural light and ventilation. 2) Lab support spaces in the heart of the plan as well as the meeting room lack natural lighting and ventilation.
IMS 	1) All floors are well lit. 2) Visibility is facilitated across the institute through the atrium. 3) The positioning of the coffee room on the ground floor only makes it the collective recreational space for all floors and the space where everybody meets.	

Table 3.2c Advantages and Disadvantages of the Architectural Design

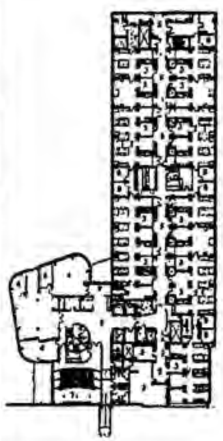
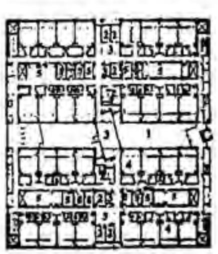
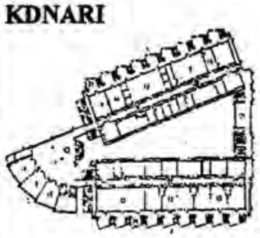
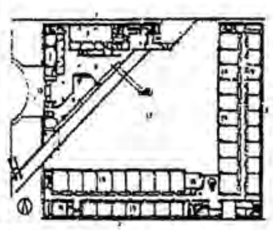
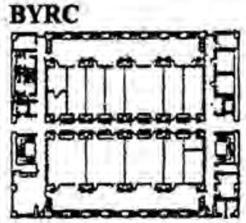
Research Centre	Advantages Of Design	Disadvantages of Design
BSC 	1) Well lit labs and offices. 2) The presence of several meeting rooms and break out areas throughout the plan facilitates interaction.	1) Although there is linking between the three buildings which facilitates movement between them but the repetition of services and facilities makes no need for inhabitants of one block to use the other block's services and facilities and thus territorial use of spaces is encouraged and interaction will be limited to interdepartmental colleagues. 2) There is no atrium to light the centre of the plan. 3) All lab support functions are artificially lit and ventilated.
SIBM 	1) There is an auditorium, meeting rooms, break out spaces and a lounge in the pavilion on each floor and scientists are invited to 'socialise' in this element. All this is to achieve communication among floor staff. 2) The pavilion break out area is close to the main building's lifts & stairs lobby which creates further communication among staff. 3) In this pavilion, there is no 'territorial' space i.e. space allocated to a certain department. Therefore the sharing of these facilities in the pavilion will encourage interdepartmental communication, all through the floor. 4) The little break out spaces along the main corridor can be used for interaction as the corridor is not the only place for circulation so it is not expected to be very busy. 5) The secondary corridor between labs encourages further communication between adjacent departments and thus strengthen departmental communication.	1) As the pavilion is 'stuck' to the building, it a *formal* communication space rather than a casual one. Scientists do not pass *by* the pavilion plan, they only go there if they have a meeting. This is different than break out areas where random and informal interaction can take place near the lab or office area. 2) Half the area of labs are not well lit, so sufficient artificial lighting has to be supplied. 3) The little number of research offices and the open lab plan makes privacy or quietness a sought after property in such a plan especially because the doorway between labs connect in the middle of the lab halfway between the main corridor and the end of the lab near the window. This could provide interruptions for the scientist who needs to have some privacy while writing up something. Moreover, interaction takes place away from the natural movement in the main corridor.
RPRRC 	1) The global linking of all buildings of the headquarters through the curved central spine. 2) The chemistry building is all well lit through the atrium. 3) The continuous linking on each floor of the two parts of the lab-based chemistry building (see **figure 3.11.3**). 4) The presence of break out areas on each floor in the way of natural movement (see **figure 3.11.3**). **5)** The presence of conference/meeting rooms on each floor in the way of natural movement (see **figure 3.11.3**). 6) The doorways between labs strengthens departmental interactions.	1) The repetition of the plan and linking it gives no need for inhabitants of one part of the floor to cross to the other part as they have the exact same facilities. 2) The shift of axis between the two corridors leading to the central link in the heart of the plan weakens visibility and thus permeability between the two sections of the building. 3) Research offices are artificially lit and ventilated and simply are rooms with no windows.

Table 3.2d Advantages and Disadvantages of the Architectural Design

Research Centre	Advantages Of Design	Disadvantages of Design
KDNARI 	1) Labs facing the courtyard are well lit. 2) All labs lie on the main corridor. 3) The presence of a spacious lobby and meeting rooms in the central building and a lounge serving the two lab wings facilitate and encourage interaction and communication among staff and in this space scientists from the east and west wings meet.	1) Back labs do not have any view or natural ventilation as they open onto a back corridor.
STRC 	1) All plan is well lit. 2) The presence of a café, foyer, restaurant, conference room and auditorium in the general facilities building facilitate communication among researchers from the whole centre and thus discouraging territorial behaviour in favour of collective use of facilities. 3) The presence of a lounge on the ground floor serving both laboratory wings facilitate communication among scientists working in the two wings.	1) The disconnection of the first floor of the two laboratory wings denies the staff of one of the wings to use the lounge on the first floor. 2) A meeting room serving the two laboratory wings could have been useful in order to facilitate meetings besides using the conference room in the general facilities building as one conference room is scarce for the whole centre. Advance booking of such a room should be a necessity.
BYRC 	1) An architecturally pleasing building from the exterior and the quality of materials in the interior. 2) The presence of meeting rooms on the ground floor and lounges on other floors facilitate communication among staff.	1) There are no lounges in building no 3 so its users are supposed to use lounges in buildings 1 or 2. 2) As building no 3 is lacking in facilities like meeting and coffee rooms, it should have been placed next to building no 1, i.e. building no 1 placed in the middle between the two buildings, or a triangular relationship of permeability should have established among the three buildings, where every building could be approached from the other two buildings without a building being farther than the other to general facilities.

3.3 Discussion:

3.3.1 Summary of the Egyptian Sample:

The **NRC** comprises of 4 floors housing 88 labs, 72 offices, 33 lab support spaces, 1 auditorium, 2 libraries, 2 conference rooms and 1 photocopying room. It lacks meeting rooms, breakout spaces, coffee rooms and a central cafe.

The **HBRC** consists of 8 floors housing 144 labs, 54 offices, 1 auditorium, 1 showroom that can be used as a meeting room, a dining room for workers and 2 small dining rooms for researchers. There is a mosque in the centre.

The **GIF** consists of 2 floors housing 46 labs, 13 offices. There is a mosque on site. The GIF totally lacks meeting facilities. This can be compared to a house where inhabitants have bedrooms to live and sleep in but do not have a living room where they can sit down and experience some kind of solidarity as members of a family.

The **NCNSRC** consists of 9 floors housing 88 labs, 72 offices, 24 lab support spaces, 1 conference room, 1 computer room & a café but it is not working yet because the administration thinks it is a time wasting element.

The **IGER** on the other hand, although it is built around the same time as the **NCNSRC** contains 3 meeting rooms and a break out area on the first floor. Clearly when the **NCNSRC** was designed there was no intention for the design to achieve promotion of interaction in the brief of the client or in the programme of the designer, although it was designed in a period where to keep the floors quiet for work quietly while all the social interaction takes place on the ground floor, the busiest floor.

3.3.3 Summary of the American Sample:

The **BSC** consists of 3 floors, housing 72 labs, 77 offices, 297 lab support spaces, 36 meeting rooms, 24 break out areas. The BSC plan highly promotes interaction but mainly on the department level as there are 3-5 meeting rooms and 3 break out spaces located in every department. Although the departments are linked, the researcher does not expect a cause for inhabitants to be travelling through departments except if they need to see a person in specific. The BSC plan is divided into three blocks, each separated from the other two by provision of the same exact services.

The **SIBM** consists of 5 floors, housing 136 labs, 35 offices, 255 lab support spaces, 4 auditoriums, 8 meeting rooms, 20 break out spaces, 8 coffee lounges. The SIBM's pavilion clearly promotes interaction among scientists, as the policy is to invite scientists to 'socialise' in this pavilion. The **RPRRC** consists of 3 floors, housing 96 labs, 141 offices, 54 lab support spaces, 18 meeting rooms, 4 break out spaces, 1 central auditorium and large ground floor café.

The plan of **RPRRC** also promotes interaction on the floor level but because it is divided into two almost identical wings, again interaction is interdepartmental but the café on the ground floor gives a chance for all employees to meet and interact.

3.3.4 Summary of the Japanese sample:

The **KDNARI** consists of 4 floors, housing 124 labs, 72 offices, 40 lab support spaces, 5 conference rooms, 2 lounges and a courtyard between them. The centre separates the hotel-like activity happening in the general facilities building from the work and interaction activity occurring in the laboratory wings and the central building by separating the buildings.

The **STRC** consists of 2 floors, housing 121 labs, 7 lab support spaces, 1 auditorium, 1 conference room, 2 lounges in the lab wings and a court between them. The STRC stresses interdepartmental communication in the east and the west labs. It also encourages all staff communication through the General Facilities Building which houses an auditorium, a café, a staff restaurant. It also encourages interaction through visibility between the lab wings and the café which is totally visible through the use of glass walls.

The **BYRC** consists of three buildings, all sharing the basement where plant rooms and parking are housed. The first building consists of 2 floors, housing the administration offices, 1 computer room, 1 guest room, lab support spaces, 2 meeting room, 1 library, 1 large conference room and 1 central café with a large break out area. The second building consists of 4 floors housing research offices and rooms and a lounge on every floor. The third building consists of 2 floors housing laboratories and research offices. The design of the BYRC encourages interdepartmental communication by creating large research offices that open to research rooms to increase communication between researchers. The meeting rooms, conference rooms and the café are housed in the administration building to encourage all staff meeting in it.

3.4 The Scoring Criteria:

Table 3.4.1 summarises the contents of the whole research centre and services available on site and gives a score for each element according to the number of boundary spaces and it attempts to make an evaluation of each of the research laboratories according to a scoring criteria. This is a substantial comparison as it points out the strength of a research centre in terms of the total number of items it offers to its users. It takes into account important factors that are as follows:

1) The architectural design that further promotes interaction, for example, the highest score is given to the research centre composed of one floor which 1/1=1, the lowest number to the research centre composed of eight floor which is 1/8= 0.125. Also the more staircases and lifts in a building the less likely people will meet while using them as they will use the closest to their locations and this will tend to segregate & localise people, so if there is one staircase in a building like in the case of IGER, the score will be 1/1=1, while if there is 16 like in the case of the NRC the score will be 1/16 = 0.06 an so forth.
2) The total number of laboratories, offices, lab support spaces are calculated for all centres and the highest score is derived from the highest number of any item in all RCs and the others get their share ratios from it. So for example, the HBRC (Egypt) contained the highest number of labs so it scored 10 in labs and the other RCs scored less in the number of labs.
3) The Interaction spaces are spaces can be identified as auditoriums, conference and seminar rooms, meeting rooms and break out spaces. The highest number of each item is scored from 5, so SIBM which

houses 4 auditoriums scores a 5 while NRC, HBRC, RPRRC and STRC each score a 1.25 and so forth in all interaction spaces.

4) The interaction/food or drink spaces which are the coffee rooms on each floor or the cafes and dining rooms serving the whole centre. The scoring criteria took into consideration that coffee rooms promote interaction among floor users but large cafes and dining rooms promote interaction among all users so the former was given a score of 1 for each coffee room or lounge on each floor and a score of 10 was given to large central cafes and dining rooms. So for example CBL, SIBM & BYRC each scored 4 and KDNARI & STRC each scored 5 for having a coffee room and a lounge on every floor but NCNSRC, SCRC, IMS, RPRRC, STRC and BYRC scored 10 for having a central café or dining room.
5) The services that promote movement from local departments like the library, central computer room and central photocopying room each score a total number of 5.
6) The item that promotes visibility among users which is the atrium, the presence of which in a RC scored a number of 5.
7) The items that promoted more happiness and well being in the RC like a central mosque and a fitness or sports centre, but because the presence of both are not directly essential in the research process, each was given a score of 1.

3.5 Summary

This chapter has architecturally reviewed the different research centres chosen for spatial analyses in the following chapter. It has also pointed out the advantages and disadvantages of each design of all the centres and offered some suggestions for solving the architectural problems to facilitate communication among researchers in those centres. It has also summarised the contents of each research centre in a comparison table in order to compare advantages and disadvantages of each research centre. The Egyptian centres except the IGER lacked meeting facilities and only NRC, HBRC and NCNSRC offered recreational facilities. Meeting rooms allow some of the users to meet up and discuss problems. Recreational facilities, not only offer food and beverage for people at work, but interaction over food or a cup of coffee can be very instrumental in mixing disciplines together in a way that can never be achieved by pre-coordinated meetings. This can only be valued if the management decided that interaction is a factor that can help in problem solving and in innovation. But if it is thought that efficiency is the only factor that it respects than the architectural plan will be used in a way that reflects the management's policy. There are two buildings in the Egyptian sample designed in the early nineties and completed a few years later, on one hand, the NCNSRC reflects no elements designed to promote interaction whereas on the other hand, the IGER is designed with a high awareness on behalf of the architect and the client not just in terms of meeting rooms but also in terms of recreational facilities through the whole Research Park. The **Egyptian** centres can be compared to a house where its users have bedrooms; each having his own bedroom, but they do not have a living room where they can interact, or sit down and talk, or a place where they can sit down and have a conversation over a cup of tea or coffee and feel their solidarity as a family or in that case as an organisation. They all possess formal lecture rooms where they can attend a lecture, but not a place for informal social interaction and communication. Some lacked lab support functions on the floor like **HBRC**, **NCNSRC**. The **IGER** centre proved to be in a different level than the first four centres in terms of promoting communication by means of meeting rooms, break out areas and lounges.

As can be noticed from the comparative analyses, that research centres of developed countries like the UK, USA and Japan provide dining facilities, like dining rooms, cafes, lounges and coffee rooms for their users. The researcher wonders why would the Egyptian research facilities, and even most organisations, choose to completely ignore this legitimate human need? Why not celebrate it and assign a proper time for it in a large collective space where researchers, scientists and even visitors could meet and practice some form of social and scientific interaction.

Chapter Four

Spatial Analyses of Research Laboratories *169-366*

4.0	Introduction	169
4.1	Sites Analyses	170-179
4.2	The spatial Analyses of Research Laboratories	180-331
4.3	Comparative Analyses	332
4.3.1	Analyses by numbers	333
4.3.2	Analyses by integration	335
4.4	Ranking of functions in research laboratories according to mean integration values	340
4.5	Justified Permeability Graphs	347
4.6	Symmetry of plans	353
4.7	Conclusions	360-364
4.8	Summary	365-366

4.0 Introduction

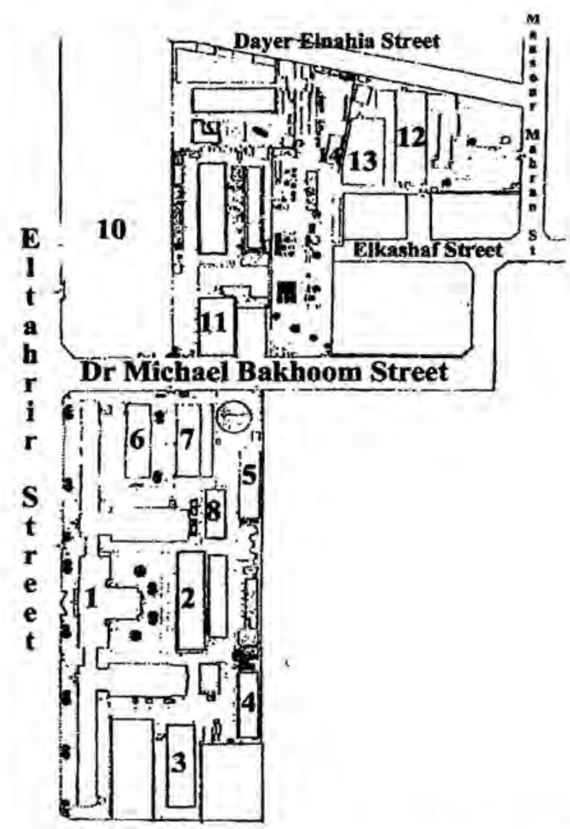
This chapter discusses the role of space configuration in promoting communication among researchers as it is argued that consultation among higher number of colleagues from outside the research group enhances problem solving[1].

In the first part of the chapter some sites of research centres are going to be reviewed according to planning criteria. In the second part of this chapter the 14 research laboratories that were architecturally reviewed in the previous chapter, will be spatially analysed using the space syntax techniques both axially and boundary[2] wise and using justified permeability graphs. As a proper analysis should be, research centres should be globally analysed, including all floors in the analyses, but in order to make a proper comparison, factors should be normalised. And because the references of the American and British research laboratories included only typical floor plans, and because of the nature of the research laboratories, where their inhabitants tend to be located around their labs and offices in the floor where they work, a decision was made to analyse and compare typical floor plans of all buildings so that a valid comparison can be implemented among them. So a choice of one floor plan had to be made. 14 chosen plans of the 14 research centres are going to be spatially analysed in the following part.

[1] Allen, Thomas. *Managing the Flow of Technology*, MIT Press, Cambridge Massachusetts and London, England, 1977.
[2] See chapter two, part 2: Methodological tools, p.37.

4.1 Sites Analyses

By looking at the different following sites of research centres, the following can be noted:



1 The NRC original building	2 Engineering Department
3 Half Industrial Experiments Building	4 Chemistry Building
5 Biology building	6 Physics building
7 Scientific Equipment building	8 Branches building. Dining room on the ground floor & a café in basement
9 Mosque	10 Housing & building research centre space
11 Office building	12 Textiles building
13 Food Industry	14 Mechanical Workshop

Figure 4.1.1 The site of the National Research Centre Complex, Giza, Egypt

The buildings are scattered across the two sites with no focal point.

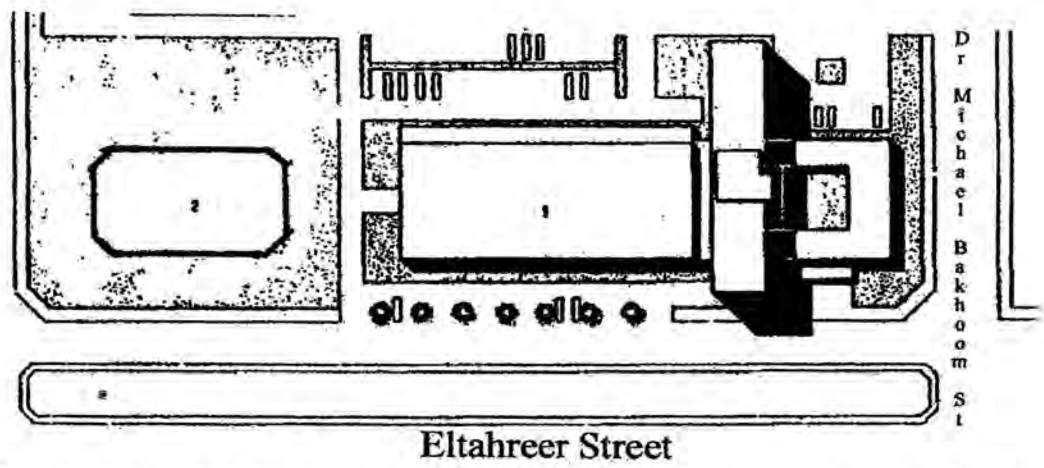
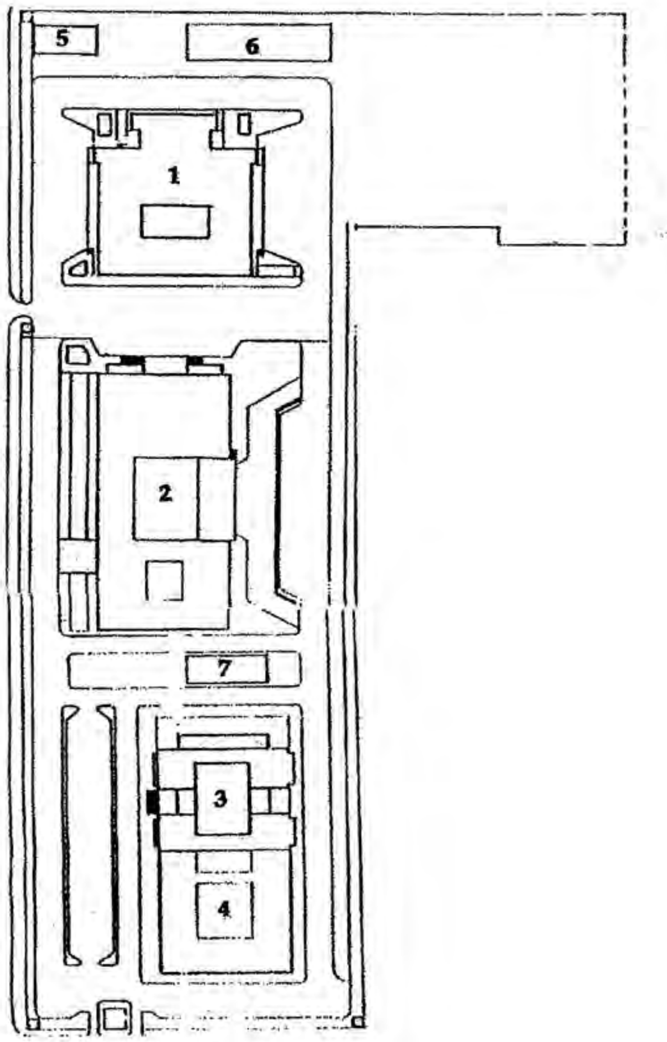


Figure 4.2.2 Site plan of the HBRC complex

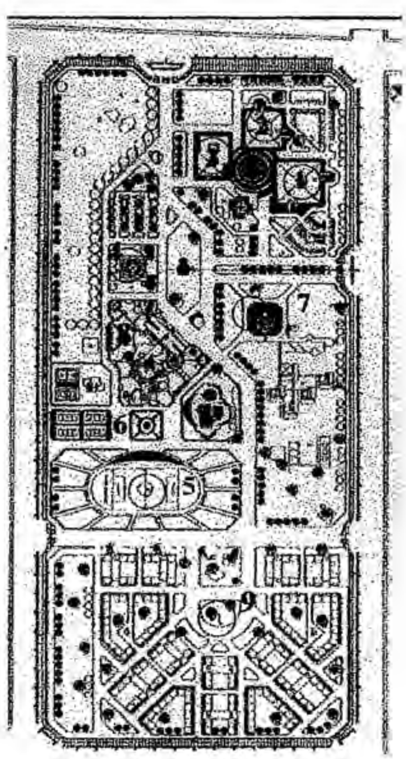
The buildings are nicely lined along the same axis but with no focus.



1 The Gamma Irradiation Facility
2 The Electron Beam Accelerator Building
3 The Administration Building
4 The Conference Centre
5 The *old* building of the National Centre for Nuclear Safety & Radiation Control
6 The *new* building of the National Centre for Nuclear Safety & Radiation Control
7 The Electric Transformers Building

Figure 4.1.3 Site plan of the Atomic Energy Authority, Nasr City
Source: The engineering department at AEA

The buildings are scattered along the site with no links and no focus.



Phase One:

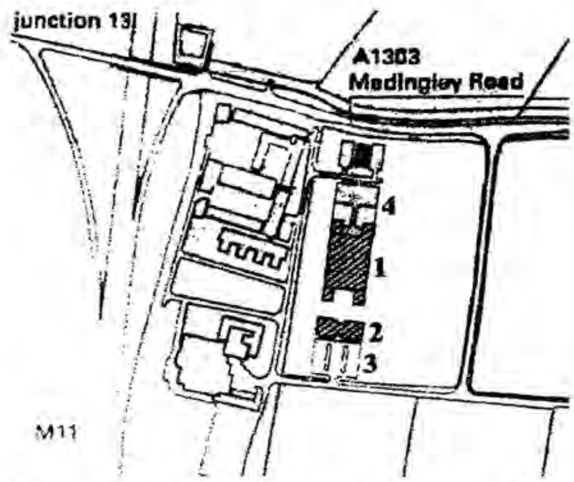
1 Institute for Genetic Engineering Research
2 Institute for New Materials and Advanced Technology
3 Institute for Informative Research

Phase Two (not built yet):

4 Building for Celebrations
5 Stadium
6 Sports Centre
7 Area for further Research Centres
8 Recreational Centre
9 Staff Accommodation

Figure 4.1.3 Site plan of Mubarak City for Scientific Research
Source: Medina Magazine, Special Issue on MCSR, December 1999

The research buildings represent a very small area compared to other functions like staff accommodation but there is a focal point among the three research centres.



1 Phase one research centre 2 Phase two research centre 3 Parking 4 Service Yard

Figure 4.1.4a Site plan of Schlumberger Cambridge Research Centre, Cambridge, UK

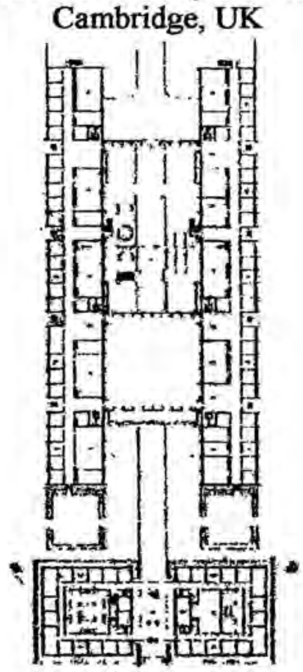
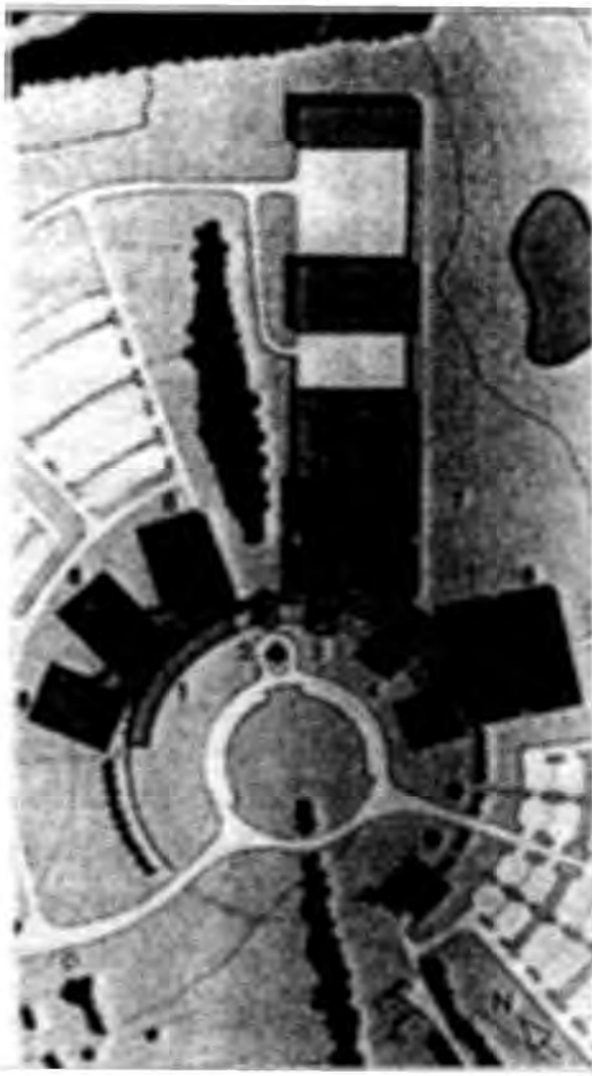


Figure 4.1.4b Site plan of Schlumberger Cambridge Research Centre

The buildings are lined along an axis in the site and the two research centres are very close together, both overlooking the café.



1 Fitness Centre	2 Lobby	3 Auditorium	4 Library
5 Dining	6 Chemistry building	7 Biology Building	8 Corporate Office

Figure 4.1.5 Site plan of the Rhone Poulenc Rorer Research Centre
The buildings are radially connected and overlooking each other with a big platform connecting the buildings.

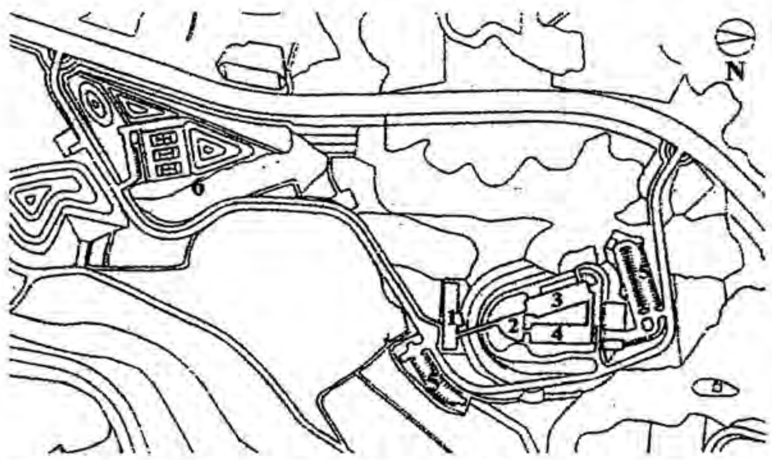


Figure 4.1.6a Site plan of Kazusa DNA Research Institute

1	General Facilities Building
2	Central Building
3	West Wing Laboratory Building
4	East Wing Laboratory Building
5	Parking Area
6	Tennis Courts

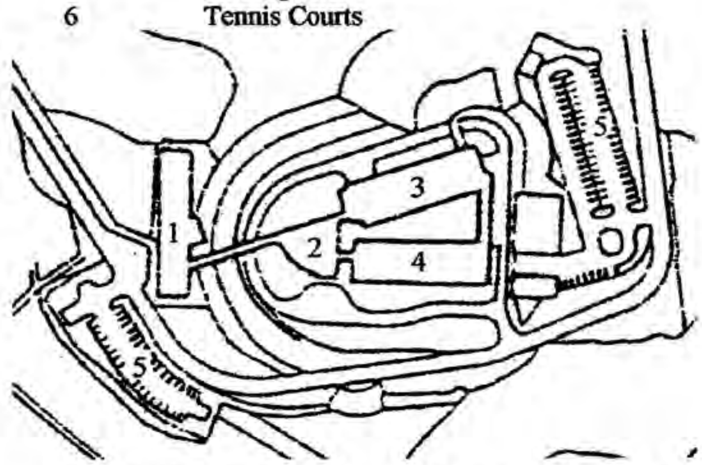
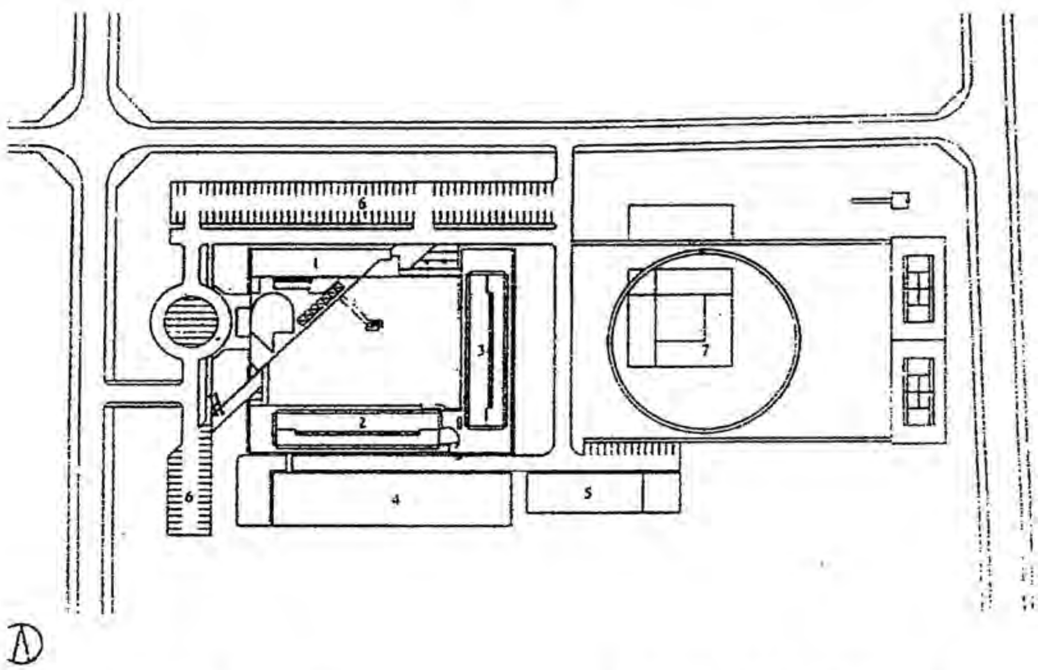


Figure 4.1.6b Site plan of Kazusa DNA Research Institute

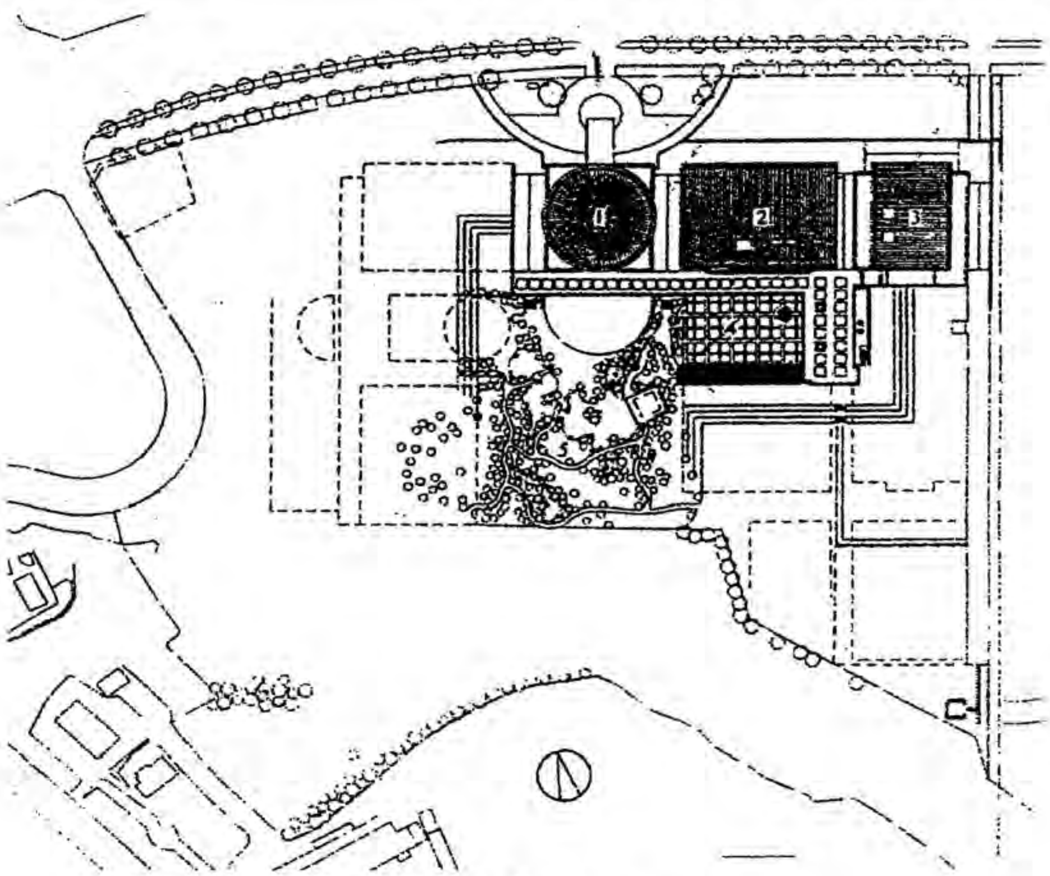
The four buildings are interconnected with a bridge between the general facilities building and the central building. Parking lots are on both sides of the site. There are tennis courts at a distance.



1 General Facilities Building
2 Research Laboratories I
3 Research Laboratories II
4 Biomedical Research Laboratories
5 Electrical Energy Supply Building
6 Parking area
7 Athletic Grounds

Figure 4.1.7 Site plan of Sandoz Tsukuba Research Centre

General facilities and research laboratories are interconnected through bridges. Athletic grounds occupy almost the same area as research buildings.



1 General Facilities Building
2 Biological research building
3 Pharmacology research building
4 Courtyard
5 Japanese garden

Figure 4.1.8 Site plan of Bayer Yakuhin Research Centre

The research buildings are horizontally aligned. It would have been better if the general facilities building would have been placed in the middle between the two research buildings or there could have been another spatial relation among the three buildings.

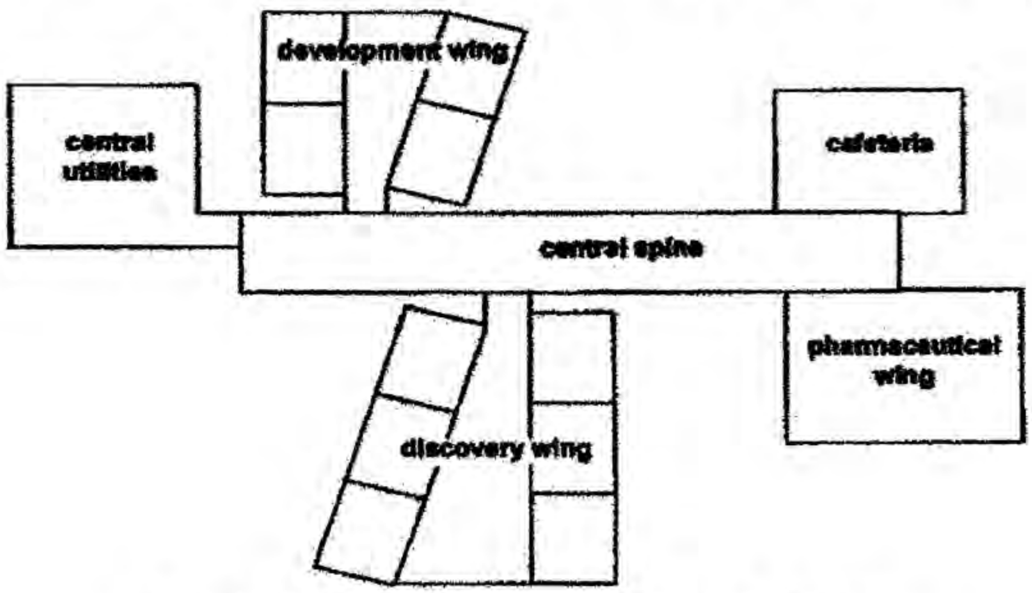


Figure 4.1.9 Schematic Site Plan of Proctor & Gamble

All wings are connected through a covered central spine. Users of all wings use the cafeteria and the central utilities, so communication is bound to occur between all users.

Summary

Some site plans promote interaction more than others. Planners have to be aware of the promotion of interaction among users of several building as well as among users of the same building.

In the following part, the previously architecturally reviewed research buildings are going to be spatially analysed.

4.2 The Spatial Analyses of Research Laboratories

In chapter one, two different British research centres were introduced through the work of Hillier & Penn. Lab 2 in **Figure 4.2b** shows the centre that was identified as to be producing better research because some of its members received Nobel prizes while Lab1 shown in **figure 4.2a** did not. Lab 1 was constructed in two phases according to a single planning system but lab 2 building is divided into the "old building"(horizontal in the plan) and the recently added "new building" (vertical in the plan) to which scientists were reluctant to move when it was built. Hillier and Penn identified differences between lab1 and the old or horizontal part of lab 2 in that the connections between labs occur deep in the lab (near the window) in lab1 while they occur shallow in the lab (near the corridor) in lab 2.

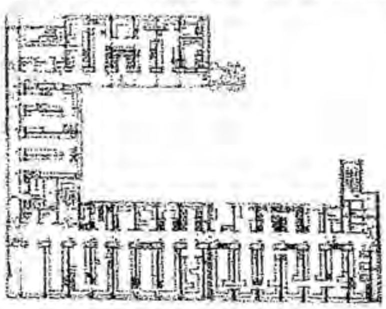


Figure 4.2a

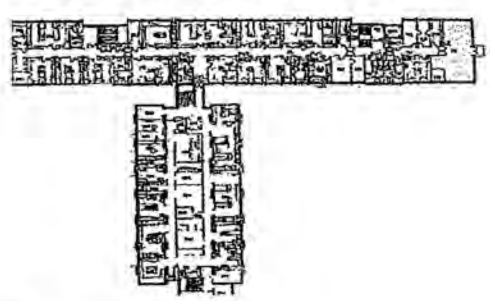


Figure 4.2b

The researcher spatially examined the architectural plans and analysed them using the space syntax techniques like axial and boundary analyses. The following results were produced:

Research Centre	**mean axial int**	**mean boundary int**
Figure 4.2a	1.26	2.07
Figure 4.2b (Horizontal Part)	1.28	2.4

According to these results a decision was made to calculate mean axial and boundary integration values and rank research centres accordingly. Justified permeability graphs In the following part each of the 14 research centres are going to be spatially analysed in several ways.

4.2.1 The National Research Centre, NRC, Dokki, Egypt

The first floor plan was chosen for spatial analysis due to the presence of the highest number of laboratories and offices in it. **Figure 4.2.1.1** is a representation of the first floor plan of NRC[3].

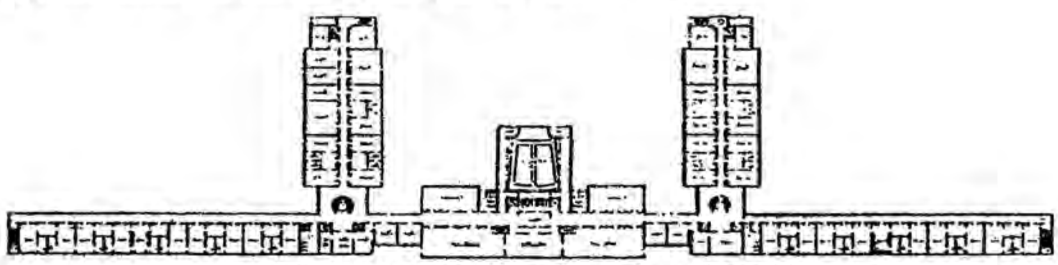


Figure 4.2.1.1 First floor plan of NRC

Figure 4.2.1.2 is an axial map of the plan representing integration (1/x RRA) values. Red represents the highest integration value followed by orange, yellow, green, light blue, dark blue and finally purple represents the most segregated lines. The lines representing the main corridors and the library are the most integrated lines of the plan. Labs and offices on the main corridors are partly segregated and the ones in the perpendicular wings are very segregated.

[3] For more architectural details of the National Research Centre refer to page 56.

	Space no	NRC Co...	NRC Int	Space name	Depth
1	5	8	1.409	stairs	1
2	87	7	1.404	circ/corridor	3
3	9	7	1.399	circ/corridor	3
4	8	3	1.385	circ/corridor	4
5	134	6	1.347	circ/corri	3
6	10	5	1.338	circ/corri	3
7	11	7	1.262	circ/corri	2
8	129	7	1.216	circ/lobby	2
9	135	20	1.205	circ/corri	2
10	91	3	1.111	theatre	4
11	56	3	1.108	theatre	4
12	57	2	1.108	lift	1
13	90	2	1.108	lift	1
14	94	2	1.096	library	4
15	6	1	1.093	circ/corridor	3
16	7	1	1.093	circ/corridor	3
17	2	1	1.093	stairs	1
18	3	1	1.093	stairs	1
19	52	2	1.093	library	4
20	93	1	1.090	archives	4
21	92	1	1.090	toilet	4
22	55	1	1.087	toilet	4
23	53	1	1.087	archives	4
24	54	3	1.084	reading hall	5
25	15	19	1.081	circ/corri	2
26	13	19	1.075	circ/corri	2
27	165	3	1.063	circ/lobby	4
28	45	3	1.060	circ/lobby	4
29	96	2	1.060	archives	4
30	95	1	1.056	archives	4
31	50	2	1.056	library	4
32	51	1	1.050	library	4
33	128	20	1.047	circ/corri	2
34	12	2	1.010	circ/lobby	3

Table 4.2.1a Spaces of NRC ranked in a descending order of integration

	Space no	NRC Co...	NRC Int	Space name	Depth
35	43	1	1.003	lift	1
36	4	1	1.003	stairs	1
37	44	1	1.003	lift	1
38	132	2	.978	lift	2
39	130	1	.973	airs	2
40	133	1	.973	lift	2
41	131	1	.973	lift	2
42	139	3	.971	lab	3
43	138	3	.971	lab	3
44	140	3	.971	lab	3
45	143	3	.971	lab	3
46	155	3	.971	lab	3
47	152	3	.971	circ/lobby	3
48	137	3	.971	circ/lobby	3
49	157	3	.971	circ/lobby	3
50	163	3	.971	circ/lobby	2
51	160	3	.971	lab	3
52	136	3	.971	lab	3
53	156	3	.971	lab	3
54	151	3	.971	lab	3
55	149	3	.970	circ/lobby	3
56	150	2	.969	lab	3
57	147	1	.966	lift	1
58	145	1	.966	lab	3
59	144	1	.966	lab	3
60	89	4	.917	theatre	5
61	58	4	.915	theatre	5
62	60	3	.910	theatre	7
63	61	3	.910	theatre	8
64	31	4	.891	lab	3
65	26	4	.891	lab	3
66	25	4	.891	lab	3
67	21	4	.891	lab	3
68	20	4	.891	lab	3

Table 4.2.1b Spaces of NRC ranked in a descending order of integration

	Space no	NRC Co..	NRC Int	Space name	Depth
69	30	4	.891	lab	3
70	17	3	.889	circ/lobby	3
71	37	3	.889	circ/lobby	3
72	22	3	.889	circ/lobby	3
73	40	3	.889	lab	3
74	27	3	.889	circ/lobby	3
75	32	3	.889	circ/lobby	3
76	16	3	.889	lab	3
77	35	3	.889	lab	3
78	36	3	.889	lab	3
79	41	2	.887	toilet	3
80	1	1	.885	stairs	1
81	85	3	.885	lab	3
82	62	3	.885	lab	3
83	63	3	.885	circ/lobby	3
84	14	3	.885	circ/corri	2
85	77	3	.885	circ/lobby	3
86	76	3	.885	lab	3
87	66	3	.885	lab	3
88	42	1	.885	lift	1
89	82	3	.885	circ/lobby	3
90	81	3	.885	lab	3
91	80	3	.885	lab	3
92	71	3	.884	circ/lobby	3
93	70	2	.883	storage	3
94	68	1	.881	storage	3
95	69	1	.881	storage	3
96	67	1	.881	storage	3
97	75	1	.881	storage	3
98	86	1	.881	lift	1
99	74	1	.881		3
100	49	2	.876	printers	5
101	97	2	.876	medical centre	5
102	111	3	.866	lab	3

Table 4.2.1c Spaces of NRC ranked in a descending order of integration

	Space no	NRC Co...	NRC Int	Space name	Depth
103	118	3	.866	circ/lobby	3
104	112	3	.866	lab	3
105	117	3	.866	lab	3
106	116	3	.866	lab	3
107	113	3	.866	circ/lobby	3
108	108	3	.866	circ/lobby	3
109	103	3	.866	circ/lobby	3
110	102	3	.866	lab	3
111	121	3	.866	lab	3
112	107	3	.866	lab	3
113	106	3	.866	lab	3
114	125	3	.865	office	4
115	126	3	.865	lab	3
116	122	3	.865	lab	3
117	123	3	.865	circ/lobby	3
118	100	2	.864	toilet	3
119	101	1	.862	lift	1
120	127	1	.862	stairs	1
121	48	3	.843	photocopier	4
122	98	2	.819	medical centre	4
123	141	2	.812	office	4
124	142	2	.812	office	4
125	164	2	.812	office	4
126	158	2	.812	office	4
127	159	2	.812	office	4
128	166	2	.812	office	4
129	153	2	.812	office	4
130	154	2	.812	office	4
131	162	1	.810	stairs	1
132	146	1	.810	storage	3
133	148	1	.809	circ/lobby	4
134	88	1	.772	theatre	6
135	59	1	.771	theatre	6
136	19	2	.755	office	4
137	33	2	.755	office	4

Table 4.2.1d Spaces of NRC ranked in a descending order of integration

	Space no	NRC Co...	NRC Int	Space name	Depth
138	24	2	.755	office	4
139	28	2	.755	office	4
140	29	2	.755	office	4
141	23	2	.755	office	4
142	39	2	.754	office	4
143	18	2	.754	office	4
144	34	2	.754	office	4
145	38	2	.754	office	4
146	79	2	.751	office	4
147	83	2	.751	office	4
148	84	2	.751	office	4
149	64	2	.751	office	4
150	65	2	.751	office	4
151	78	2	.751	office	4
152	46	1	.750	toilet	4
153	161	1	.749	stairs	1
154	73	1	.749	storage	3
155	72	1	.748	storage	4
156	119	2	.737	office	4
157	120	2	.737	office	4
158	115	2	.737	office	4
159	104	2	.737	office	4
160	105	2	.737	office	4
161	109	2	.737	office	4
162	110	2	.737	office	4
163	114	2	.737	office	4
164	124	2	.736	office	4
165	99	1	.734	toilet	4
166	47	1	.719	room	5

Table 4.2.1e Spaces of NRC ranked in a descending order of integration

If we collect the same space names and get their mean boundary integration and then rank them in order of integration, the result is the following relationship:

corridors >	library >	archives >	auditorium >	lobbies >	labs >	toilets >
1.201	1.079	1.073	.994	.931	.908	.902

storage >	med centre >	photocopying rm >	offices
.848	.847	.843	.766

Figure 4.2.1.7 is a justified permeability graph of the first floor plan drawn from the exterior as a root. There are four bushes of labs shown by a clear pattern where the labs lead to the offices and are shallower in depth than the offices. Labs occupy depth 3 while offices occupy depth 4. The offices cannot be reached independently. Inhabitants i.e. scientists as well as visitors cannot reach the offices without passing through the labs and invading the classification of work. The graph is symmetrical around the middle axis and has got some rings. Maximum depth is **6** which is the interior of the auditorium. Mean depth is **3.23**. Relative ringiness is 250/167 = **1.497**.

Figure 4.2.1.8 is a justified permeability graph of the floor plan drawn from the most integrated space (space 5). The maximum depth remains **6**. Mean depth is **4.62**.

Figure 4.2.2.3 is a regression showing the intelligibility of the first floor of HBRC. R-squared value is .218 which is a low value meaning that the first floor plan is not a very intelligible plan.

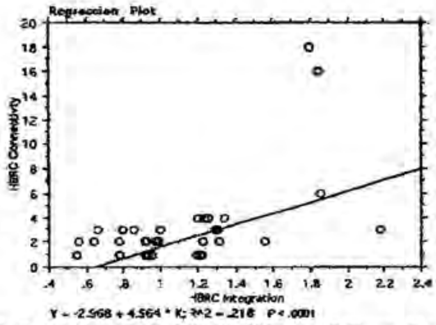


Figure 4.2.2.3 Axial Intelligibility of first floor of HBRC

Figure 4.2.2.4 is a bar chart showing the integration value of each axial line on the first floor of HBRC arranged in a descending order. The chart reflects the high values of integration of the lobbies and corridors followed by many lines of the same value, which represent the offices and laboratories followed by a group of lines representing the corridors leading to the café, the showroom and the 2nd floor of the auditorium.

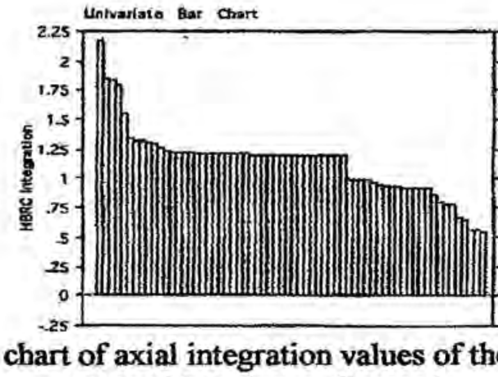


Figure 4.2.2.4 Bar chart of axial integration values of the first floor of HBRC arranged in a descending order

Figure 4.2.2.5 is a boundary map of the rooms and spaces of the plan, each given a number from 1 till 62. The different colours represent different functions. **Figure 4.2.2.6** is the boundary integration core of the first floor of HBRC. The most integrated space is the lobby number 5 where it leads to the main lift lobby and the two corridors leading to the labs and offices. The most segregated spaces are the 2nd floor of the auditorium and the staircase of the dining room and the rooms at the end of the library. Mean integration is **1.464**.

	Space no	HBRC Connect...	Space name	HBRC Int	Depth
1	3	5	lobby	2.693	2
2	4	16	Circ/ corridor	2.106	2
3	5	17	Circ/ corridor	2.106	2
4	1	9	Lift lobby	2.106	2
5	6	2	Circ/corridor	1.730	3
6	19	1	stairs	1.530	1
7	20	1	stairs	1.530	1
8	2	6	circ/corri	1.428	4
9	10	3	library	1.400	5
10	45	3	circ/corri	1.390	3
11	51	3	lobby	1.355	2
12	54	3	lobby	1.355	1
13	57	3	lobby	1.355	2
14	48	3	lobby	1.346	2
15	50	2	toilet	1.338	2
16	31	1	lab	1.321	3
17	37	1	lab	1.321	3
18	36	1	lab	1.321	3
19	33	1	lab	1.321	3
20	32	1	lab	1.321	3
21	35	1	lab	1.321	3
22	34	1	lab	1.321	3
23	38	1	lab	1.321	3
24	43	1	Office	1.321	3
25	44	1	office	1.321	3
26	60	1	stairs	1.321	1
27	42	1	office	1.321	3
28	39	1	office	1.321	3
29	40	1	office	1.321	3
30	41	1	office	1.321	3
31	21	1	office	1.321	3
32	22	1	office	1.321	3
33	23	1	office	1.321	3
34	18	1	showroom	1.321	3

Table 4.2.2a Spaces of HBRC ranked in a descending order of integration

	Space no	HBRC Connect...	Space name	HBRC Int	Depth
35	9	1	stairs	1.321	1
36	8	1	lift	1.321	1
37	7	1	lift	1.321	1
38	28	1	lab	1.321	3
39	30	1	lab	1.321	3
40	29	1	lab	1.321	3
41	27	1	lab	1.321	3
42	24	1	office	1.321	3
43	25	1	office	1.321	3
44	26	1	office	1.321	3
45	14	2	dinning room	1.028	2
46	11	2	library	1.023	6
47	16	1	kitchen	1.018	4
48	17	1	kitchen	1.018	4
49	61	1	private dining	1.018	4
50	62	1	private dining	1.018	4
51	46	2	lobby	1.008	4
52	56	1	toilet	.980	2
53	58	1	stairs	.980	1
54	59	1	toilet	.980	2
55	55	1	stairs	.980	2
56	53	1	toilet	.980	2
57	52	1	stairs	.980	1
58	49	1	stairs	.976	1
59	12	2	library	.800	7
60	15	1	stairs	.797	1
61	47	1	auditorium	.785	5
62	13	1	library	.653	8

Table 4.2.2b Spaces of HBRC ranked in a descending order of integration

	Space no	GIF connect	GIF 1/x RRA	space name	depth
35	40	3	1.071	office WS	4
36	5	4	1.063	circ/lobby	2
37	10	2	1.058	ante lab NL	2
38	28	1	1.058	surveillance room	4
39	53	1	1.058	surveillance room	4
40	16	2	1.058	toilet NL	3
41	18	2	1.058	lab NL	3
42	8	2	1.055	lab NL	3
43	20	1	1.055	storage	3
44	9	2	1.055	ante lab NL	2
45	2	1	1.053	Stairs NL	2
46	14	1	1.053	office RA	2
47	36	1	1.053	office NL	2
48	34	1	1.053	office RA	2
49	30	1	1.053	toilet NL	2
50	12	1	1.053	office NL	2
51	37	1	1.053	office NL	2
52	13	1	1.053	office NL	2
53	38	1	1.053	office NL	2
54	35	1	1.053	office NL	2
55	1	1	1.053	Circ/Entrance lobby	2
56	7	1	1.053	lab NL	2
57	19	1	1.053	lab NL	2
58	29	1	1.053	lab NL	2
59	15	1	1.053	lab N L	2
60	55	3	1.032	area behind radiation source	5
61	41	3	1.008	office WS	4
62	39	2	.985	office WS	5
63	73	2	.931	radiation control room	5
64	63	2	.917	ante office RA	4
65	33	1	.915	office NL	4
66	61	1	.913	lab: RA	4
67	62	1	.909	lab: RA	4
68	58	1	.909	office RA	4

Table 4.2.3b Spaces of GIF ranked in a descending order of integration (1/x RRA)

	Space no	GIF connect	GIF 1/x RRA	space name	depth
69	56	4	.905	area behind radiation source	6
70	23	3	.898	lab CourtYard	4
71	25	2	.896	lab courtyard	3
72	24	2	.894	lab courtyard	3
73	69	3	.884	area behind radiation source	5
74	90	1	.877	lab: RA	5
75	67	2	.875	area behind radiation source	4
76	88	1	.874	lab: RA	5
77	93	1	.874	lab: RA	5
78	100	3	.851	circ/ent ramp	6
79	17	1	.849	lab NL	3
80	11	1	.846	lab NL	3
81	74	2	.834	radiation source	6
82	72	2	.817	area behind radiation source	7
83	81	4	.770	corridor SL	7
84	70	2	.748	area behind radiation source	7
85	75	3	.745	circ/Entrance lobby	7
86	22	2	.743	lab back area	4
87	95	4	.741	circ/ decontamination ent ...	6
88	26	2	.741	lab courtyard	4
89	102	1	.708	circ/ent ramp	7
90	80	4	.659	circ/lobby	8
91	83	1	.651	toilet SL	8
92	71	1	.635	area behind radiation source	8
93	76	1	.633	Stairs SL	8
94	84	2	.633	decontamination showers	7
95	21	1	.632	lab Back area	5
96	86	1	.631	storage	7
97	96	1	.631	circ/ent ramp	7
98	27	1	.631	lab courtyard	5
99	78	2	.571	lab: SL	9
100	79	1	.570	lab: SL	9
101	82	1	.570	lab: SL	9
102	85	1	.550	changing room	8
103	77	1	.503	lab: SL	10

Table 4.2.3c Spaces of GIF ranked in a descending order of integration (1/x RRA)

Mean boundary integration value of the floor is 1.748. According to this value, integration is highest in the corridor, which makes a lot of sense as this corridor is the only way for almost any movement from anywhere to anywhere, except between department heads and their secretaries. So let us find out how this floor gets used. The NCNSRC administration believes that efficiency lies in the decentralisation of services, so every department has its own photocopying machine placed in the room of the secretary for the sake of efficiency and time saving (see **figure 4.2.4.1**). There are no coffee rooms on any floor for the same reason. There are no meeting rooms on the floor or on any other floor except for formal monthly meetings which takes place in the department heads' offices. Toilets are scattered across the floor so every department has its own toilets. Even the café on the top floor has not been completed for fear of time consumption by the staff. So movement for the sake of staff interaction is not at all encouraged in the floor or in the building. And although the corridor is the only space where everybody should meet everybody, they rarely do because everybody should be seated all day in their office or laboratory trying to 'work'. Furthermore, a phenomena has been noticed by the researcher and it is that the doors of all rooms, labs and offices, that have a glass window to promote visibility from the corridor to the rooms and vice versa, many of these windows have been covered with sheets of paper as shown in figures **4.2.4.8a-c**. So all of the four factors mentioned above help to reduce communication through the way the building gets used as a result of managerial decisions which are the laws of type two mentioned earlier [7].

[7] See chapter two p.38.

	Space No	NCNSRC Connectivity	NCNSRC 1/x RRA	Space Name
1	6	31	11.455	Corridor
2	2	5	2.864	Lift lobby
3	25	4	2.739	lobby
4	14	3	2.625	lobby
5	42	2	2.520	stairs
6	43	2	2.520	lobby
7	27	1	2.423	office
8	37	1	2.423	lab
9	39	1	2.423	office
10	38	1	2.423	office
11	40	1	2.423	secretary
12	34	1	2.423	office
13	33	1	2.423	lab
14	36	1	2.423	office
15	35	1	2.423	office
16	32	1	2.423	architects' room
17	29	1	2.423	department head
18	28	1	2.423	office
19	31	1	2.423	office
20	30	1	2.423	office
21	21	1	2.423	lab
22	10	1	2.423	Toilet
23	11	1	2.423	lab
24	9	1	2.423	Toilet
25	7	1	2.423	Toilet
26	8	1	2.423	Toilet
27	12	1	2.423	office
28	19	1	2.423	Air conditioning
29	20	1	2.423	Air conditioning
30	18	1	2.423	lab
31	13	1	2.423	office
32	41	1	2.423	department head
33	3	1	1.482	Lift
34	1	1	1.482	Stairs
35	5	1	1.482	Lift
36	4	1	1.482	Lift
37	23	1	1.448	kitchenette
38	22	1	1.448	Toilet
39	24	1	1.448	Toilet
40	16	1	1.416	Stairs
41	15	1	1.416	Lift
42	26	1	1.385	stairs
43	17	1	1.385	toilet

Table 4.2.4 Spaces of NCNSRC ranked in a descending order of integration

4.2.5 Institute for Genetic Engineering, IGER, Mubarak City for Scientific Research, New Borg El-Arab, Egypt

The plan chosen for spatial analysis was the first floor of the institute as it is the one most consisting of labs and offices. **Figure 4.2.5.1** is a representation of the first floor plan of IGER[8].

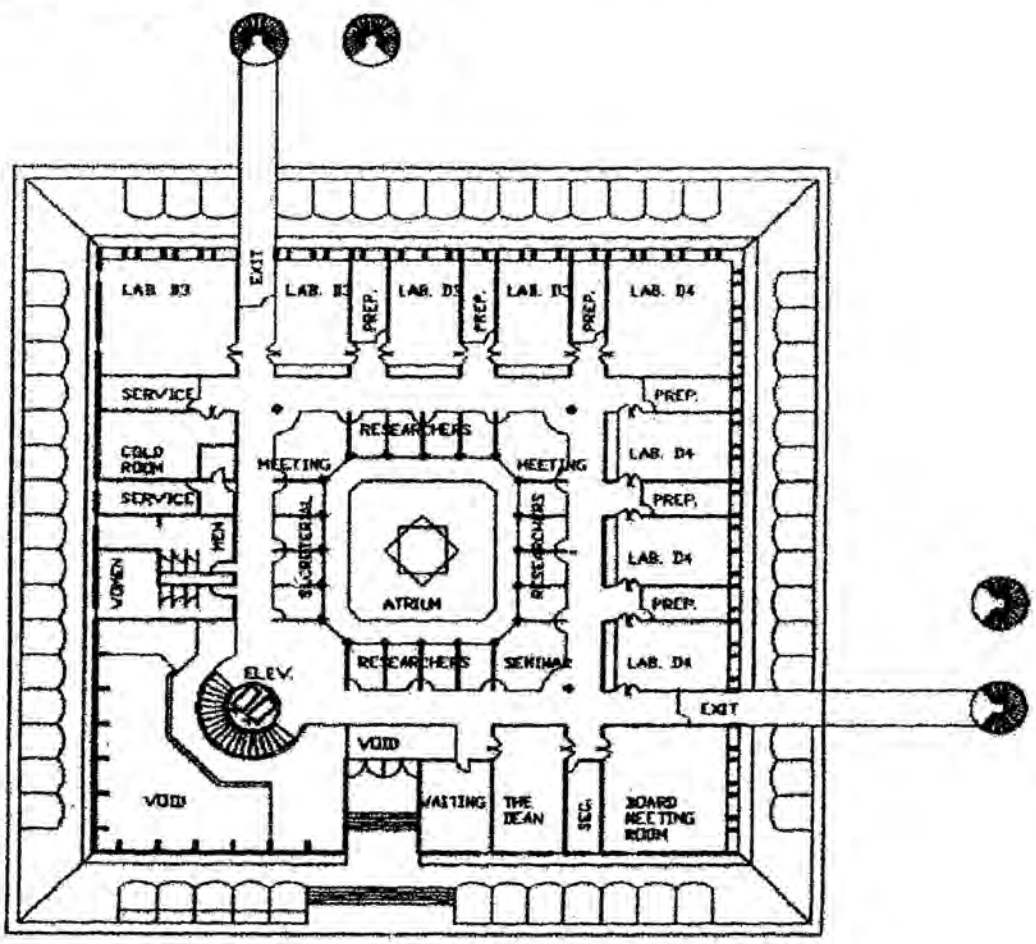


Figure 4.2.5.1 First floor of IGER, MCSR

[8] For more architectural details of the Institute for Genetic Engineering, refer to page 82.

Figure 4.2.5.2 is an axial map of the IGER plan representing integration (1/x RRA) values. Red represents the highest integration value of axial lines followed by orange, yellow, green, light blue, dark blue and finally purple represents the most segregated lines. The most integrated line in the floor is the red one representing a corridor in the square surrounding the atrium, followed by an orange and two yellow ones. Also there is an orange line which is the corridor connecting the labs to each other followed by a green one connecting the other set of labs together. Mean axial integration value is 1.345.

	Space no	IGER Connect	IGER 1/x RRA	Space name	Depth
1	6	14	2.689	circ/corridor	3
2	7	12	2.575	circ/corridor	1
3	5	10	2.373	circ/corridor	1
4	8	10	2.200	circ/corridor	1
5	4	6	2.086	circ/lobby	2
6	24	2	1.891	meeting room	2
7	29	2	1.806	meeting room	1
8	19	2	1.704	meeting room	2
9	11	4	1.613	circ/lobby	1
10	12	4	1.613	circ/lobby	1
11	9	4	1.592	circ/corridor	2
12	10	3	1.592	circ/lobby	1
13	56	4	1.572	circ/lobby	2
14	26	1	1.551	office	1
15	57	3	1.551	circ/lobby	2
16	25	1	1.551	office	1
17	27	1	1.551	office	1
18	42	1	1.551	lab	1
19	43	1	1.551	lab prep	1
20	28	1	1.551	office	1
21	44	1	1.551	lab	1
22	20	1	1.513	office	2
23	50	1	1.513	service room	2
24	21	1	1.513	office	2
25	22	1	1.513	office	2
26	23	1	1.513	office	2
27	36	2	1.494	lab	2
28	13	4	1.494	circ/lobby	2
29	14	3	1.476	circ/lobby	2
30	55	3	1.476	Circ/lift lobby	2
31	64	2	1.458	circ/ corridor	2
32	30	1	1.441	office	2
33	31	1	1.441	office	2
34	60	3	1.424	circ/lobby	2

Table 4.2.5a Spaces of IGER ranked in a descending order of integration

	Space no	IGER Connect	IGER 1/x RRA	Space name	Depth
35	54	1	1.375	toilet	2
36	18	1	1.375	office	2
37	53	1	1.375	toilet	2
38	17	1	1.375	office	2
39	15	1	1.375	office	2
40	16	1	1.375	office	2
41	58	3	1.360	circ/lobby	3
42	63	2	1.345	board room	3
43	59	1	1.330	main stairs	3
44	1	1	1.330	lift	1
45	38	2	1.152	lab	2
46	40	2	1.142	lab	2
47	48	2	1.142	lab	3
48	66	2	1.120	circ/corridor	3
49	37	1	1.120	lab prep	2
50	39	1	1.120	lab prep	2
51	46	2	1.120	lab	3
52	49	1	1.110	lab	3
53	41	1	1.110	lab prep	2
54	47	1	1.100	lab prep	3
55	45	1	1.090	lab prep	3
56	33	2	1.080	board/dean	3
57	35	1	1.061	board room ...	3
58	34	1	1.061	board/secret...	3
59	32	1	1.052	board/dean	3
60	3	1	1.052	lift	1
61	2	1	1.052	lift	1
62	65	1	1.043	fire exit	3
63	61	2	1.034	circ/lobby	3
64	52	1	1.026	service	3
65	62	2	1.000	circ/corridor	4
66	68	1	.992	meeting area	5
67	67	1	.858	fire exit	4
68	51	1	.807	cold room	4

Table 4.2.5b Spaces of IGER ranked in a descending order of integration

	Space no	SCRC con...	SCRC 1/x RRA	Space name	depth
1	18	6	2.287	cafe/restaurant	0
2	2	44	2.274	circ/corri	2
3	14	4	2.235	circ/lobby	1
4	15	3	2.222	circ/lobby	1
5	17	3	2.161	drilling court	4
6	6	4	2.149	circ/lobby	1
7	7	4	2.149	circ/lobby	1
8	10	4	2.126	circ/lobby	3
9	12	2	2.126	circ/lobby	3
10	1	41	2.115	circ/corri	2
11	16	2	2.070	circ/link	4
12	3	4	2.059	circ/lobby	3
13	4	2	2.059	circ/lobby	3
14	13	2	1.764	circ/lobby	2
15	11	2	1.733	circ/lobby	3
16	8	2	1.688	circ/lobby	2
17	5	2	1.688	circ/lobby	2
18	9	2	1.667	circ/lobby	3
19	97	1	1.473	circ/ent ramp	1
20	68	1	1.468	office	3
21	67	1	1.468	office	3
22	63	1	1.468	office	3
23	65	1	1.468	office	3
24	64	1	1.468	office	3
25	66	1	1.468	office	3
26	56	1	1.468	office	3
27	61	1	1.468	office	3
28	57	1	1.468	office	3
29	62	1	1.468	office	3
30	58	1	1.468	office	3
31	55	1	1.468	office	3
32	51	1	1.468	office	3
33	54	1	1.468	office	3
34	52	1	1.468	office	3

Table 4.2.6a Spaces of SCRC ranked in a descending order of integration

	Space no	SCRC con...	SCRC 1/x RRA	Space name	depth
35	45	1	1.468	office	3
36	44	1	1.468	office	3
37	53	1	1.468	office	3
38	49	1	1.468	office	3
39	48	1	1.468	office	3
40	46	1	1.468	office	3
41	50	1	1.468	office	3
42	47	1	1.468	office	3
43	60	1	1.468	office	3
44	85	1	1.468	lab	3
45	88	1	1.468	lab	3
46	90	1	1.468	lab	3
47	87	1	1.468	lab	3
48	86	1	1.468	circ/lobby	2
49	78	1	1.468	lab	3
50	79	1	1.468	lab	3
51	84	1	1.468	lab	3
52	83	1	1.468	lab	3
53	59	1	1.468	office	3
54	82	1	1.468	lab	3
55	89	1	1.468	lab	3
56	81	1	1.468	lab	3
57	80	1	1.468	lab	3
58	95	1	1.451	toilet	2
59	96	1	1.446	toilet	2
60	92	1	1.415	toilet	2
61	93	1	1.415	toilet	2
62	94	1	1.405	toilet	4
63	39	1	1.400	office	3
64	74	1	1.400	lab	3
65	77	1	1.400	lab	3
66	69	1	1.400	lab	3
67	70	1	1.400	lab	3
68	76	1	1.400	lab	3

Table 4.2.6b Spaces of SCRC ranked in a descending order of integration

	Space no	SCRC con...	SCRC 1/x RRA	Space name	depth
69	75	1	1.400	lab	3
70	42	1	1.400	office	3
71	43	1	1.400	office	3
72	41	1	1.400	office	3
73	40	1	1.400	office	3
74	37	1	1.400	office	3
75	38	1	1.400	office	3
76	71	1	1.400	lab	3
77	36	1	1.400	office	3
78	35	1	1.400	office	3
79	33	1	1.400	office	3
80	21	1	1.400	office	3
81	34	1	1.400	office	3
82	31	1	1.400	office	3
83	30	1	1.400	office	3
84	28	1	1.400	office	3
85	32	1	1.400	office	3
86	29	1	1.400	office	3
87	24	1	1.400	office	3
88	27	1	1.400	office	3
89	25	1	1.400	office	3
90	73	1	1.400	lab	3
91	72	1	1.400	lab	3
92	19	1	1.400	office	3
93	22	1	1.400	office	3
94	20	1	1.400	office	3
95	26	1	1.400	office	3
96	23	1	1.400	office	3
97	91	1	1.375	toilet	4

Table 4.2.6c Spaces of SCRC ranked in a descending order of integration

If we collect the same spaces and get their mean boundary integration and then arrange them in order of integration, the result is the following relationship:

Café/2 corridors/drilling court/ break out area/ link/ lobby / ent ramp/
2.287 / 2.194/ 2.151 / 2.141 /2.07 / 1.668/ 1.473/

lab / office / toilets
1.438/ 1.434 / 1.42

Figure 4.2.6.7 is a justified permeability graph of the ground floor plan of SCRC drawn from the exterior. The graph is symmetrical around the middle axis producing two bushes of labs & offices each with links joining the two bushes. Offices and labs occupy depth 2. The max depth is **3** while the mean depth **2.07**. The graph is a ringy through the café and bridges connecting the two wings. Relative ringiness or space-link ratio is 113/97= **1.15**.

Figure 4.2.6.8 is a justified permeability graph of the ground floor plan of SCRC drawn from the most integrated space (space 18: café). The max depth is **4** while the mean depth **3.01**.

Integrating factor of most integrated space: **2.07/3.01= 0.68**

	Space no	CBL Connect	CBL 1/x RRA	Space name	Depth
1	7	13	1.926	circ/corridor	2
2	8	7	1.878	circ/corridor	1
3	12	4	1.804	Circ/corridor	0
4	5	11	1.804	circ/corridor	1
5	17	2	1.790	lab	2
6	6	10	1.762	circ/corridor	2
7	24	2	1.748	coffee room	2
8	9	3	1.353	circ/corridor	3
9	45	5	1.321	lab	2
10	10	3	1.299	circ/corridor	4
11	42	3	1.299	lab	3
12	11	2	1.291	circ/corridor	3
13	39	3	1.284	lab	3
14	43	2	1.284	lab	3
15	4	2	1.270	circ/corridor	3
16	31	3	1.270	lab	2
17	23	1	1.256	Toilet	3
18	20	1	1.256	lab	3
19	19	1	1.256	lab	3
20	38	1	1.256	lab	3
21	60	1	1.256	duct/storage	3
22	59	1	1.256	duct/storage	3
23	58	1	1.256	duct/storage	3
24	32	3	1.249	lab	3
25	25	2	1.242	lab	2
26	57	1	1.235	duct/storage	2
27	50	1	1.235	duct/storage	1
28	33	4	1.222	lab	3
29	3	2	1.215	circ/corridor	2
30	22	1	1.203	toilet	2
31	61	1	1.203	duct/storage	2
32	18	1	1.203	lab	2
33	21	1	1.203	lab	2
34	62	1	1.203	duct/storage	2

Table 4.2.7a Spaces of CBL ranked in a descending order of boundary integration

	Space no	CBL Connect	CBL 1/x RRA	Space name	Depth
35	15	1	1.203	lift	1
36	13	1	1.203	stairs	1
37	63	1	1.203	duct/storage	2
38	37	1	1.184	lab	3
39	65	1	1.184	duct/storage	3
40	64	1	1.184	duct/storage	3
41	14	1	1.184	meeting room	3
42	52	5	1.019	circ/corridor	4
43	44	2	.997	lab	4
44	51	2	.992	lab	3
45	47	2	.988	lab	4
46	46	2	.984	lab	3
47	41	2	.971	lab	4
48	48	1	.967	office	3
49	49	1	.967	office	3
50	30	2	.963	lab	3
51	16	1	.955	stairs	5
52	34	2	.951	office	4
53	40	1	.947	lab	4
54	26	2	.947	lab	3
55	2	1	.939	lift	4
56	35	1	.913	office	4
57	36	1	.913	office	4
58	1	1	.909	stairs	3
59	56	1	.795	unknown	5
60	53	1	.795	unknown	5
61	55	1	.795	stairs	5
62	54	1	.795	unknown	5
63	29	2	.776	lab	4
64	27	2	.765	lab	4
65	28	2	.649	lab	5

Table 4.2.7b Spaces of CBL ranked in a descending order of integration

	Space no	IMS CONNECT...	IMS 1/x RRA	Space name	depth
35	58	2	1.094	lab entrance	3
36	60	2	1.094	lab entrance	3
37	65	2	1.090	lab entrance	4
38	61	2	1.090	lab entrance	3
39	59	2	1.090	lab entrance	3
40	29	4	1.087	circ/corri	4
41	81	2	1.084	lab end	6
42	41	2	1.077	circ/corri	3
43	22	1	1.071	office	3
44	90	1	1.071	storage	4
45	24	1	1.071	office	3
46	23	1	1.071	office	3
47	66	1	1.071	storage	4
48	25	1	1.071	office	3
49	21	1	1.071	office/write ...	3
50	83	1	1.071	storage	4
51	67	1	1.071	storage	4
52	62	1	1.071	storage	3
53	71	1	1.071	storage	4
54	70	1	1.071	storage	4
55	69	1	1.071	storage	4
56	68	1	1.071	storage	4
57	28	1	.958	stairs	4
58	46	3	.940	circ/corri	4
59	55	2	.916	lab	4
60	53	2	.916	lab	4
61	10	2	.914	coffee area	3
62	44	3	.911	lab	5
63	7	1	.909	reception&ph...	3
64	43	2	.907	lab	4
65	3	2	.907	circ/corri	4
66	45	2	.907	lab	4
67	2	2	.895	circ/corri	4
68	36	3	.893	lab	5

Table 4.2.8b Spaces of IMS ranked in a descending order of integration

	Space no	IMS CONNECT...	IMS 1/x RRA	Space name	depth
69	64	1	.893	stairs	1
70	37	3	.893	lab	4
71	35	3	.891	lab	4
72	38	3	.886	lab	4
73	1	2	.884	reception	5
74	33	3	.882	lab	4
75	40	2	.873	lab	4
76	30	1	.857	stairs	5
77	89	1	.857	storage	3
78	63	1	.850	stairs	1
79	47	4	.773	circ/corri	5
80	52	1	.763	storage	5
81	54	3	.756	lab	5
82	11	1	.745	service	4
83	39	3	.736	lab	5
84	34	2	.727	lab	5
85	49	1	.649	toilet	6
86	51	1	.649	toilet	6
87	50	1	.649	toilet	6
88	84	1	.637	lab end	6
89	82	1	.623	lab end	6
90	80	1	.616	lab end	6

Table 4.2.8c Spaces of IMS ranked in a descending order of integration

Figure 4.2.8.7 is a justified permeability graph of the ground floor plan of IMS drawn from the exterior. Offices occupy depth 4 while labs occupy depth 6. The max depth is **7** while the mean depth **4.28**. The circulation spaces are ringy and the labs have rings inside them. Relative ringiness is 103/90= **1.14**.

Figure 4.2.8.7 is a justified permeability graph of the ground floor plan drawn from the most integrated space of IMS (space number 12: corridor).

Tables 4.2.9a-d represent the boundary integration values of the second floor of BSC arranged in a descending order of integration.

	Space number	BSC connect...	BSC int (1/x RRA)	Space name
1	51	10	1.893	corridor
2	50	9	1.887	corridor
3	48	11	1.881	corridor
4	49	9	1.875	corridor
5	62	10	1.790	link
6	43	10	1.769	link
7	55	5	1.576	break out ...
8	59	5	1.572	break out ...
9	67	12	1.519	corridor
10	78	9	1.474	corridor
11	41	11	1.470	corridor
12	42	11	1.467	corridor
13	112	2	1.388	lab support
14	101	2	1.381	lab support
15	104	3	1.347	lift lobby
16	109	1	1.338	stairs
17	110	1	1.338	toilet
18	111	1	1.338	toilet
19	11	1	1.338	lab
20	12	1	1.338	lab
21	113	1	1.335	lab support
22	14	1	1.335	lab
23	13	1	1.335	lab
24	10	1	1.332	lab
25	100	1	1.332	lab support
26	9	1	1.332	lab
27	108	1	1.332	lab support
28	107	1	1.332	labsupport
29	99	1	1.332	lab support
30	103	1	1.329	lab support
31	15	1	1.329	lab
32	16	1	1.329	lab
33	102	1	1.329	lab support
34	64	1	1.285	meeting rm

Table 4.2.9a Spaces of the second floor of BSC ranked in a descending order of integration (1/x RRA)

	Space number	BSC connect...	BSC int (1/x RRA)	Space name
35	65	1	1.285	office
36	66	1	1.285	office
37	60	1	1.285	office
38	61	1	1.285	office
39	63	1	1.285	meeting rm
40	45	1	1.274	meeting rm
41	44	1	1.274	meeting rm
42	47	1	1.274	office
43	46	1	1.274	office
44	38	1	1.274	office
45	37	1	1.274	office
46	76	9	1.240	corridor
47	39	11	1.207	corridor
48	40	10	1.204	corridor
49	82	5	1.195	break out ...
50	71	5	1.195	break out ...
51	53	1	1.171	meeting rm
52	54	1	1.171	office
53	52	1	1.171	office
54	57	1	1.169	meeting rm
55	58	1	1.169	office
56	56	1	1.169	office
57	36	5	1.162	break out ...
58	32	5	1.162	break out ...
59	83	2	1.157	corridor
60	85	2	1.148	lab support
61	115	1	1.139	lab support
62	114	1	1.139	lab support
63	17	1	1.139	lab
64	18	1	1.139	lab
65	129	1	1.139	lab support
66	130	1	1.139	lab support
67	131	1	1.139	lab support
68	128	1	1.139	lab support

Table 4.2.9b Spaces of the second floor of BSC ranked in a descending order of integration

	Space number	BSC connect...	BSC int (1/x RRA)	Space name
69	116	1	1.114	lab support
70	117	1	1.114	toilet
71	24	1	1.114	lab
72	119	1	1.114	lab support
73	118	1	1.114	toilet
74	23	1	1.114	lab
75	91	1	1.112	lab support
76	89	1	1.112	lab support
77	90	1	1.112	lab support
78	5	1	1.112	lab
79	6	1	1.112	lab
80	92	1	1.112	lab support
81	87	1	1.110	lab support
82	132	1	1.110	lab support
83	3	1	1.110	lab
84	88	1	1.110	lab support
85	4	1	1.110	lab
86	86	1	1.110	lab support
87	105	1	1.040	lift
88	106	1	1.040	lift
89	77	10	1.030	corridor
90	75	5	1.004	break out ...
91	28	5	.992	break out ...
92	20	1	.975	lab
93	19	1	.975	lab
94	126	1	.975	lab support
95	125	1	.975	lab support
96	127	1	.975	lab support
97	84	1	.954	lab support
98	98	1	.954	lab support
99	2	1	.954	lab
100	1	1	.954	lab
101	97	1	.954	stairs
102	8	1	.953	lab
103	7	1	.953	lab

Table 4.2.9c Spaces of the second floor of BSC ranked in a descending order of integration

	Space number	BSC connect...	BSC int (1/x RRA)	Space name
104	93	1	.953	lab support
105	95	1	.953	toilet
106	94	1	.953	toilet
107	96	1	.953	lab support
108	81	1	.947	office
109	80	1	.947	office
110	68	1	.947	office
111	69	1	.947	meeting rm
112	79	1	.947	office
113	70	1	.947	office
114	30	1	.926	meeting rm
115	29	1	.926	office
116	35	1	.926	office
117	34	1	.926	meeting rm
118	31	1	.926	office
119	33	1	.926	office
120	123	1	.840	lab support
121	124	1	.840	stairs
122	21	1	.840	lab
123	120	1	.840	lab support
124	22	1	.840	lab
125	122	1	.840	lab support
126	121	1	.840	lab support
127	72	1	.823	office
128	73	1	.823	meeting rm
129	74	1	.823	office
130	27	1	.815	office
131	26	1	.815	meeting rm
132	25	1	.815	office

Table 4.2.9d Spaces of the second floor of BSC ranked in a descending order of integration

	Space no	SIBM connecti...	SIBM 1/x ...	Space name
35	77	1	1.968	storage
36	76	1	1.968	storage
37	78	1	1.968	storage
38	79	1	1.968	storage
39	75	1	1.968	stairs
40	23	1	1.968	lift
41	81	1	1.968	storage
42	24	1	1.968	lab support
43	80	1	1.968	storage
44	82	1	1.968	storage
45	83	1	1.968	lab support
46	6	5	1.769	lobby
47	3	1	1.565	lift
48	2	1	1.565	lift
49	21	1	1.565	lab support
50	22	1	1.565	lab support
51	4	1	1.565	lift
52	96	5	1.550	corridor
53	91	6	1.530	lab
54	102	8	1.525	lab
55	59	6	1.516	lab
56	64	4	1.507	lab
57	41	6	1.502	lab
58	90	4	1.502	lab
59	46	4	1.488	lab
60	54	4	1.484	corridor
61	67	4	1.479	lab
62	37	4	1.479	corridor
63	86	4	1.466	lab
64	49	3	1.448	lab
65	112	3	1.431	corridor
66	101	1	1.419	lab support
67	100	1	1.419	lab support
68	55	1	1.399	lab support

Table 4.2.10b Spaces of SIBM ranked in a descending order of integration (1/x RRA)

	Space no	SIBM connecti...	SIBM 1/x ...	Space name
69	40	1	1.399	stairs
70	110	1	1.399	lab support
71	31	1	1.387	lab support
72	71	1	1.367	lab support
73	58	1	1.364	lab support
74	19	3	1.309	Lounge
75	10	4	1.302	lobby
76	9	2	1.288	auditorium
77	7	4	1.278	corridor
78	38	3	1.159	corridor
79	98	2	1.146	office
80	97	2	1.146	office
81	92	1	1.133	lab support
82	95	1	1.133	lab support
83	106	1	1.130	lab support
84	107	1	1.130	lab support
85	60	1	1.125	lab support
86	63	1	1.125	lab support
87	66	1	1.120	lab support
88	42	1	1.117	lab support
89	45	1	1.117	lab support
90	89	1	1.117	lab support
91	73	2	1.109	lobby
92	47	1	1.109	lab support
93	52	1	1.107	office
94	53	1	1.107	office
95	68	1	1.104	lab support
96	36	1	1.104	office
97	51	1	1.087	lab support
98	113	1	1.078	storage
99	18	2	1.034	Conference rm
100	111	3	1.034	corridor
101	14	1	1.006	kitchenette
102	20	1	1.002	main staircase
103	13	1	1.002	cloak room

Table 4.2.10c Spaces of SIBM ranked in a descending order of integration (1/x RRA)

	Space no	SIBM connecti...	SIBM 1/x ...	Space name
104	1	1	.988	stairs
105	33	1	.988	lab support
106	34	1	.988	lab support
107	35	1	.916	office
108	70	1	.884	office
109	11	6	.859	break out area
110	8	2	.856	conference ro...
111	15	1	.718	Administration
112	12	1	.718	Service
113	16	1	.718	Administration
114	17	1	.718	Administration

Table 4.2.10d Spaces of SIBM ranked in a descending order of integration (1/x RRA)

If we collect the same space names and get their mean boundary integration and then arrange them in order of integration, the result is the following relationship:

Main corridor > storage > lab support > little corridors > labs > stairs >
3.589 1.875 1.665 1.649 1.59 1.452

lobbies > auditorium > offices > lounges > pavilion staircase > meeting rms >
1.393 1.288 1.286 1.013 1.002 .945

breakout area > administration
.859 .718

Figure 4.2.10.7 is a justified permeability graph of the second floor plan drawn from the exterior of the floor. Labs occupy depth 3&4 while offices occupy depth 3, 4 & 5. The max depth is **6** while the mean depth **2.955**. The graph is bushy with rings connecting the main circulation spaces. Relative ringiness is 151/126= **1.2**.

Figure 4.2.10.8 is a justified permeability graph of the second floor plan drawn from the most integrated space (space number 25: main corridor). The max depth is **5** while the mean depth is **1.849**.

Shallowness factor of most integrated space: **2.955 / 1.849 = 1.598**.

	Space no	Space name	RPRRC 1/x...
35	192	toilet	1.206
36	165	lab lobby	1.206
37	182	office	1.206
38	174	office	1.206
39	170	lab support	1.206
40	169	lab support	1.206
41	191	toilet	1.206
42	159	lab lobby	1.206
43	152	lab lobby	1.205
44	157	lab lobby	1.205
45	35	lab lobby	1.203
46	20	lab lobby	1.202
47	24	lab lobby	1.202
48	121	lab lobby	1.202
49	115	lab lobby	1.202
50	129	lab lobby	1.201
51	133	lab lobby	1.201
52	138	lab lobby	1.201
53	134	lab lobby	1.201
54	73	lab lobby	1.201
55	78	lab lobby	1.201
56	16	lab lobby	1.201
57	74	lab lobby	1.201
58	21	lab lobby	1.201
59	69	lab lobby	1.201
60	65	lab lobby	1.198
61	155	office	1.196
62	200	stairs	1.196
63	64	lab lobby	1.196
64	163	office	1.196
65	150	conference room	1.196
66	47	lab support	1.195
67	38	stairs	1.195
68	45	lab support	1.195

Table 4.2.11b Spaces of RPRRC ranked in a descending order of integration

	Space no	Space name	RPRRC 1/x...
69	43	lab support	1.195
70	63	lab lobby	1.194
71	110	lab lobby	1.194
72	62	lab lobby	1.194
73	131	office	1.191
74	118	lab lobby	1.191
75	136	office	1.191
76	67	toilet	1.191
77	18	office	1.191
78	71	office	1.191
79	88	lab support	1.191
80	41	conference room	1.191
81	89	lab support	1.191
82	68	toilet	1.191
83	76	office	1.191
84	39	stairs	1.191
85	116	office	1.188
86	125	lab support	1.188
87	44	lab support	1.187
88	171	lab end	1.134
89	198	storage	1.124
90	195	storage	1.124
91	197	storage	1.124
92	196	storage	1.124
93	93	storage	1.121
94	92	storage	1.121
95	60	storage	1.121
96	94	storage	1.121
97	91	storage	1.121
98	172	stairs	1.120
99	194	storage	1.120
100	193	storage	1.120
101	98	storage	1.117
102	97	storage	1.117
103	95	storage	1.117

Table 4.2.11c Spaces of RPRRC ranked in a descending order of integration

	Space no	Space name	RPRRC 1/x...
104	96	storage	1.117
105	148	meeting room	1.115
106	149	meeting room	1.115
107	7	meeting room	1.112
108	6	meeting room	1.112
109	154	lab	1.051
110	127	lab support	1.003
111	31	office	.989
112	185	lab	.988
113	188	lab	.988
114	180	lab	.988
115	29	office	.986
116	176	lab	.986
117	3	lab	.983
118	190	office	.983
119	183	office	.983
120	179	office	.983
121	112	lab	.981
122	123	lab	.981
123	166	lab	.981
124	14	lab	.981
125	161	lab	.981
126	4	lab	.980
127	158	lab	.980
128	27	office	.980
129	13	lab	.979
130	15	lab	.979
131	52	lab	.978
132	143	lab	.978
133	81	lab	.978
134	80	lab	.978
135	79	office	.978
136	82	lab	.978
137	139	lab	.978
138	145	lab	.978

Table 4.2.11d Spaces of RPRRC ranked in a descending order of integration

	Space no	Space name	RPRRC 1/x...
139	141	lab	.978
140	164	office	.977
141	160	office	.977
142	156	office	.976
143	153	office	.976
144	36	office	.975
145	8	lab	.975
146	9	lab	.975
147	34	office	.975
148	53	lab	.975
149	1	lab	.975
150	25	office	.974
151	114	office	.974
152	19	office	.974
153	122	office	.974
154	23	office	.974
155	137	office	.973
156	135	office	.973
157	132	office	.973
158	72	office	.973
159	77	office	.973
160	17	office	.973
161	75	office	.973
162	22	office	.973
163	70	office	.973
164	130	office	.973
165	51	lab	.972
166	50	lab	.972
167	55	office	.971
168	54	office	.971
169	57	office	.970
170	56	office	.970
171	111	lab	.968
172	109	office	.968
173	59	office	.968
174	58	office	.968

Table 4.2.11e Spaces of RPRRC ranked in a descending order of integration

	Space no	Space name	RPRRC 1/x...
175	117	office	.966
176	173	lab end	.934
177	187	lab end	.833
178	186	lab end	.833
179	11	lab end	.832
180	181	lab end	.832
181	32	lab lobby	.832
182	177	lab end	.831
183	124	lab end	.829
184	12	lab end	.829
185	10	lab end	.829
186	113	lab end	.829
187	167	lab end	.828
188	162	lab end	.828
189	86	lab end	.825
190	83	lab end	.825
191	85	lab end	.825
192	84	lab end	.825
193	144	lab end	.825
194	140	lab end	.825
195	142	lab end	.825
196	146	lab end	.825
197	120	lab end	.719
198	33	office	.716
199	2	lab	.716
200	119	lab	.630

Table 4.2.11f Spaces of RPRRC ranked in a descending order of integration

If we collect the same space names and get their mean boundary integration and then rank them in order of integration, the result is the following relationship:

Central corridor > corridors > coffee break > break out areas > toilets >
1.604 1.577 1.422 1.415 1.198

conference rms > lab entrances > stairs > lab support > meeting rms >
1.194 1.191 1.175 1.16 1.114

offices > labs > lab ends
1.016 .962 .842

Figure 4.2.11.7 is a justified permeability graph of the second floor plan of RPRRC drawn from the exterior. The graph consists of eight bushes with rings linking them. Offices occupy depths 3, 4, 5, 6 while labs occupy depths 4, 5, 6 & 7. The max depth is **7** while the mean depth **4.55**. Relative ringiness is 233/200= **1.165**.

Figure 4.2.11.8 is a justified permeability graph of the second floor plan of RPRRC drawn from the most integrated space (space number 102: corridor). The max depth is **7** while the mean depth **3.15**.

Shallowing factor of most integrated space: **4.55/ 3.15 = 1.44.**

Figure 4.2.12.3 is a regression showing the intelligibility of the first floor of KDNARI. R-squared value is **.552** which means intelligibility is average in the floor.

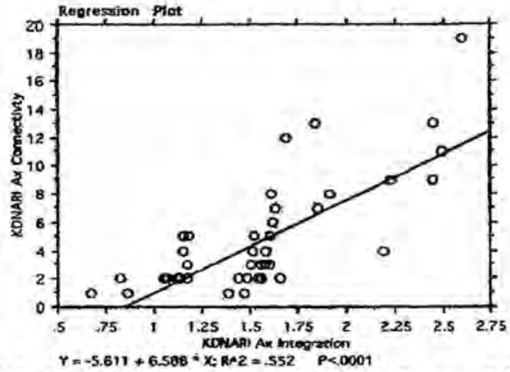


Figure 4.2.12.3 Intelligibility of first floor of KDNARI

Figure 4.2.12.4 is a bar chart showing the integration value of each axial line on the third floor of KDNARI arranged in a descending order. It is partly structured on the left of the graph then turns into an ordered chart where many groups of lines have similar values. These lines represent the groups of labs and groups of offices.

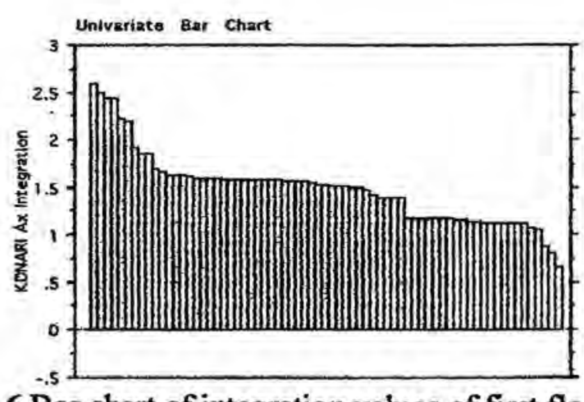


Figure 4.2.12.6 Bar chart of integration values of first floor of KDNARI arranged in a descending order

Figure 4.2.12.5 is a boundary map of the first floor plan, each given a number from 1 till 94. The different colours represent different functions. **Figure 4.2.12.6** is a boundary integration core of the first floor of KDNARI. The central building and the corridors are the most integrated spaces, followed by the laboratories. The little lounge offices are the most segregated spaces which means they are quiet and have privacy.

Tables 4.2.12a-c represent the integration values of all spaces of the first floor of KDNARI arranged in a descending order of integration.

If we collect the same space names and get their mean boundary integration and then rank them in order of integration, the result is the following relationship:

Lift lobby >	corridors >	labs >	stairs >	lifts >	lounge >	seminar rms >	toilets>
2.655	2.187	1.687	1.608	1.593	1.558	1.503	1.253

Offices >	lab support
1.321	1.309

	Space no	KDNARI Con...	KDNARI 1/x RRA	Space name
35	61	1	1.646	lab
36	68	1	1.646	lab
37	22	1	1.611	lab
38	21	1	1.611	lab
39	2	1	1.611	lift
40	23	1	1.611	lab
41	20	1	1.611	lab
42	17	1	1.611	lab
43	12	1	1.611	stairs
44	19	1	1.611	lab
45	18	1	1.611	lab
46	4	1	1.611	seminar room
47	33	1	1.611	storage
48	6	1	1.611	seminar room
49	5	1	1.611	seminar room
50	25	1	1.611	lab
51	24	1	1.611	lab
52	3	1	1.611	lift
53	26	1	1.611	lab
54	73	1	1.558	toilet
55	74	1	1.558	stairs
56	75	1	1.558	lift
57	71	1	1.558	Lounge
58	72	1	1.558	toilet
59	85	2	1.423	DNA sequence...
60	37	1	1.342	lounge
61	38	1	1.342	lounge
62	35	1	1.342	lounge
63	36	1	1.342	lounge
64	39	1	1.342	lounge
65	42	1	1.342	lounge
66	43	1	1.342	lounge
67	40	1	1.342	lounge
68	41	1	1.342	lounge

Table 4.2.12b Spaces of KDNARI ranked in a descending order of integration

	Space no	KDNARI Con...	KDNARI 1/x RRA	Space name
69	49	1	1.309	lab support
70	50	1	1.309	lab support
71	47	1	1.309	lab support
72	48	1	1.309	lab support
73	51	1	1.309	lab support
74	52	1	1.309	lab support
75	87	1	1.300	lounge
76	90	1	1.300	lounge
77	91	1	1.300	lounge
78	11	1	1.300	lounge
79	88	1	1.300	lounge
80	89	1	1.300	lounge
81	93	1	1.300	lounge
82	92	1	1.300	lounge
83	16	1	1.300	corridor
84	58	1	1.278	toilet
85	59	1	1.278	toilet
86	53	1	1.265	lab support
87	15	1	1.253	toilet
88	79	2	1.253	joint room
89	77	2	1.253	joint room
90	14	1	1.253	toilet
91	83	1	1.244	joint room
92	8	1	1.178	toilet
93	9	1	1.178	toilet
94	10	1	1.178	seminar room

Table 4.2.12c Spaces of KDNARI ranked in a descending order of integration

	Space No	STRC Con...	STRC 1/x RRA	Space name
35	56	1	1.883	lab
36	55	1	1.883	lab
37	58	1	1.883	lab
38	57	1	1.883	lab
39	52	1	1.883	lab
40	51	1	1.883	lab
41	54	1	1.883	lab
42	53	1	1.883	lab
43	40	1	1.883	lab
44	39	1	1.883	lab
45	42	1	1.883	lab
46	41	1	1.883	lab
47	12	2	1.390	corri
48	24	1	1.372	lift
49	61	1	1.372	storage
50	59	1	1.372	lounge
51	25	1	1.372	storage
52	26	1	1.372	storage
53	36	1	1.372	toilet
54	7	1	1.372	stairs
55	35	1	1.372	toilet
56	62	1	1.372	stairs
57	34	1	1.372	storage
58	38	1	1.338	lift
59	9	1	1.274	storage
60	8	1	1.274	stairs
61	10	1	1.274	corri
62	11	1	.999	storage

Table 4.2.13b Spaces of STRC ranked in a descending order of integration

If we collect the same space names and get their mean boundary integration and then rank them in order of integration, the result is the following relationship:

Corridors >	lobbies >	labs >	lab support >	lounge >	lift >	stairs >	ent lobby
3.531	2.182	1.985	1.41	1.372	1.355	1.34	1.274

Figure 4.2.13.7 is a justified permeability graph of the ground floor lab wing plan drawn from the exterior of the floor. The graph consists of two bushes of labs coming out from the corridors. Labs occupy depth **4**. The max depth is **5** while the mean depth **3.45**. The graph is a bushy one. Relative ringiness is 65/62= **1.048**.

Figure 4.2.13.8 is a justified permeability graph of the ground floor lab wing plan drawn from the most integrated space (space number 2: corridor). The maximum depth is **4** while the mean depth **1.66**.

Shallowing factor of most integrated space: **3.45 / 1.66= 2.078**

	Space no	BYRC Con...	Space name	BYRC1/x RRA
1	7	14	corridor	4.248
2	6	10	corridor	2.930
3	23	9	office	2.832
4	8	8	corridor	2.575
5	24	8	office	2.236
6	15	3	lab	1.888
7	33	2	coffee break	1.808
8	18	2	lab	1.770
9	17	2	lab	1.770
10	22	2	lab	1.770
11	21	2	lab	1.770
12	20	2	lab	1.770
13	19	2	lab	1.770
14	14	2	lab	1.770
15	11	2	lab	1.770
16	10	2	lab	1.770
17	12	2	lab	1.770
18	13	2	lab	1.770
19	16	2	lab	1.634
20	5	2	lift lobby	1.465
21	27	1	lab support	1.416
22	26	1	lab support	1.416
23	29	1	lab support	1.416
24	28	1	lab support	1.416
25	25	1	lab support	1.416
26	4	1	stairs	1.416
27	9	2	lift lobby	1.370
28	31	1	toilet	1.328
29	32	1	toilet	1.328
30	30	1	storage	1.328
31	2	1	stairs	1.328
32	3	1	lift	.955
33	1	1	lift	.914

Table 4.2.14 Spaces of BYRC ranked in a descending order of integration (1/x RRA)

If we collect the same space names and get their mean boundary integration and then rank them in order of integration, the result is the following relationship:

corridors >	offices >	lounge >	labs >	lift lobby >	lab support >	stairs >	toilets >	lifts
3.251	2.534	1.808	1.769	1.418	1.401	1.372	1.328	.934

Figure 4.2.14.7 is a justified permeability graph of the second floor plan of the biological research building drawn from the exterior of the floor. The graph consists of two connected bushes coming out from the corridors. The max depth is **5** while the mean depth **3.96**. The graph is a ringy one. Relative ringiness is 52/33= **1.575**.

Figure 4.2.14.8 is a justified permeability graph of the second floor plan of the biological research building drawn from the most integrated space (space number 7: central corridor). The maximum depth is **3** while the mean depth is **1.667**.

Shallowing factor of most integrated space: **3.96 / 1.667 = 2.375**.

4.3 *Comparative Analyses*

The following comparative analyses can be made.

1) By classifying the architectural plans according to the number of axial lines and boundary spaces of each floor, then they can be classified according to size.
2) By examining the base difference factor of integration of all laboratory floors, it can be concluded whether laboratories are different or similar in their genotypes.[18]
3) The higher the mean integration value of each floor, the higher the rate of interaction that it would be expected to induce among its inhabitants.
4) By examining mean integration values of similar functions on every floor, they can be ranked according to mean integration value of functions.
5) By comparing mean depths of JPG[19] drawn from the exterior of the floor as a root, to the mean depth of JPG drawn from the most integrated space in the floor, the shallowness[20] or deepening factor can be concluded.

[18] Hillier, B., Hanson, J., Graham, H., "Ideas are in things: an application of the space syntax method to discovering housing genotypes", Environment and Planning B, Volume 14, p. 364, 1987.
[19] Justified Permeability Graphs.
[20] This factor is devised by researcher, which results by dividing the mean depth of a JPG drawn from the exterior by the mean depth of the same graph drawn from the most integrated space. This is a measure of how the most integrated space shallows all other spaces from it.

4.3.1 Analyses by number

If we examine the number of lines and boundary spaces in each floor, and if we find the average number of lines and boundary spaces per floor, floors plan can be classified according to size. **Table 4.3.1.1** represents the number of axial lines of the different research centres arranged in a descending order.

Name of Research laboratory	Number of axial lines
NRC (Egypt)	171
RPRRC (USA)	147
GIF (Egypt)	119
BSC (USA)	101
SCRC (UK)	91
SIBM (USA)	80
IGER (Egypt)	79
KDNARI (Japan)	69
IMS (UK)	68
CBL (UK)	66
HBRC (Egypt)	64
STRC (Japan)	33
NCNSRC (Egypt)	22
BYRC (Japan)	22

Then if we get the mean number of axial lines of all research centres, which is **80.85**, then above this number the floor is considered bigger than average and below this number the floor is considered smaller than average. The American sample is all bigger than average. The NRC and GIF from Egypt are larger than average and the British SCRC is a larger than average plan. The Japanese sample are all smaller than average in axial lines and the British CBL and IMS are smaller than average in size.

Table 4.3.1.2 represents the number of boundary spaces arranged in a descending order

Research Centre	Number of Boundary Spaces
RPRRC (USA)	200
NRC (Egypt)	166
BSC (USA)	149
SIBM (USA)	126
GIF (Egypt)	102
SCRC (UK)	98
KDNARI (Japan)	94
IMS (UK)	90
IGER (Egypt)	70
CBL (UK)	65
STRC (Japan)	62
HBRC (Egypt)	62
NCNSRC (Egypt)	44
BYRC (Japan)	33

Table 4.3.1.2 Mean number of boundary spaces of each floor of research centres arranged in a descending order

Then if we get the mean number of spaces of all research centres, which is **97.2**, then above this number the floor is considered bigger than average and below this number the floor is considered smaller than average. The American sample is all bigger than average. The NRC and GIF from Egypt are larger than average and the British SCRC is a larger than average plan. The Japanese sample and the British CBL and IMS are smaller than average in size.

4.3.2 Analyses by Integration

4.3.2.1 Axial Integration Analyses

Table 4.3.2.1 represents base difference factor[21] for the minimum, mean and maximum axial integration of the different research centres

Research Centre	Axial Integration			Base Difference Factor
	Min.	Mean	Max.	
NRC	.645	1.169	1.829	.8
HBRC	.55	1.137	2.2	.7
GIF	.46	1.054	2.011	.63
NCNSRC	.75	2.015	6.429	.23
IGER	.748	1.345	2.48	.73
SCRC	1.002	1.813	3.503	.70
CBL	.582	1.24	2.299	.70
IMS	.645	1.082	2.017	.74
BSC	.716	1.051	1.716	.84
SIBM	.87	1.623	3.291	.66
RPRRC	.987	1.562	3.203	.73
KDNARI	.673	1.485	1.927	.80
STRC	.794	1.6	4.248	.47
BYRC	.75	1.76	3.214	.64

Table 4.3.2.1 Base difference factor for the minimum, mean and maximum axial integration values

[21] Base difference factor is the difference factor for the minimum, maximum and mean integration values in the complex, and thus gives some indication of how much differentiation is available in that complex, which may or may not be taken up by the various functions. It is calculated by the formula

H= -Sum [a/t* ln (a/t)] + [b/t ln (b/t)] + [c/t * ln (c/t)]

where **a=min, b=mean, c=max and t=a+b+c. BDF=** $\frac{H - \ln 2}{\ln 3 - \ln 2}$

The base difference factor is very strong in the case of NCNSRC and STRC in **table 4.3.2.1**. **Table 4.3.2.2** represents the base difference factor for the minimum, mean and maximum boundary integration of the 14 centres.

Research Centre	Boundary Integration			Base Difference Factor
	Min	Mean	Max	
NRC	.719	.918	1.409	.90
HBRC	.921	1.464	2.917	.73
GIF	.503	.999	1.585	.76
NCNSRC	1.279	1.748	5.429	.50
IGER	.81	1.39	2.597	.74
SCRC	1.375	1.545	2.287	.94
CBL	.649	1.179	1.926	.77
IMS	.616	1.035	1.616	.74
BSC	.585	.813	1.269	.88
SIBM	.566	.939	1.349	.86
RPRRC	.511	.933	1.586	.77
KDNARI	1.178	1.59	2.752	.84
STRC	.999	1.922	5.189	.47
BYRC	.914	1.762	4.248	.55

Table 4.3.2.2 Base difference factor for the minimum, mean and maximum boundary integration values

The base difference factor is very strong in the cases of NCNSRC, STRC and BYRC. The difference in genotype between those three floor plans and those of the rest of the plans is recognised by the strong base difference factor. This has to do with the very high integration value of the main corridor in the three floors. Because the three research centres consist of very small simple plans with central corridors, it has been decided to compare them among each other.

Table 4.3.2.3 represents the mean of the mean axial and boundary integration values, then the floors of research centres will be ranked according to these values.

Research Centres	Mean Axial Integration	Mean boundary Integration	Mean of mean Integration
NRC	1.169	.918	**1.04**
HBRC	1.137	1.46	**1.3**
GIF	1.054	.999	**1.03**
NCNSRC	1.606	1.748	**1.68**
IGER	1.345	1.39	**1.38**
SCRC	1.813	1.545	**1.68**
CBL	1.24	1.179	**1.21**
IMS	1.082	1.035	**1.06**
BSC	1.051	1.159	**1.1**
SIBM	1.623	1.558	**1.59**
RPRRC	1.562	1.109	**1.34**
KDNARI	1.485	1.59	**1.54**
STRC	1.6	1.923	**1.76**
BYRC	1.76	1.762	**1.76**

Table 4.3.2.3 Mean of mean axial and mean boundary integration values

Tables 4.3.2.4a ranks the three research centres with a different genotype according to their score in the previous table in a descending order of mean integration while **table 4.3.2.4b** ranks the rest of the research centres in a descending order of mean integration.

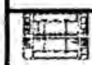
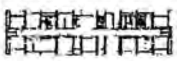
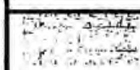
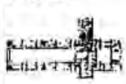
Floor plan	Research Centre	Mean of mean Integration
	BYRC	1.761
	STRC	1.761
	NCNSRC	1.677

Table 4.3.2.4a Genotypically different plans ranked in descending order

Floor plan	Research Centre	Mean of mean Integration
	SCRC	1.679
	SIBM	1.59
	KDNARI	1.537
	IGER	1.375
	RPRRC	1.3355
	HBRC	1.3
	CBL	1.21
	BSC	1.1
	IMS	1.06
	NRC	1.04
	GIF	1.03

Tables 4.3.2.4b Ranking of floors of research centres in a descending order of mean axial and boundary integration.

If we look at the typical plans of the centres carefully from bottom to up, the **GIF** plan has got some design problems as it is very segregated in some parts. The **NRC** plan is symmetrical with one link between the two parts of the plan, the **IMS** plan is symmetrical, the **BSC** plan is symmetrical along the two axes. The **CBL** plan is spatially symmetrical though not metrically. Half of the **HBRC** plan is symmetrical. The **RPRRC** plan is symmetrical with three links between the two parts of the plan.

If we look at the highest scoring top seven plans in integration value, we will find that they are all individual plans with no symmetry or repetition except the **SCRC** plan, but then the two wings are very highly connected through the links and the café.

This brings us to a very important conclusion, which is that making the floor bigger by making symmetry around an axis or mirroring a part of a building and linking it is a bad idea for achieving a well linked building architecturally designed to promote communication. Besides, symmetrical plans mean repeating not only rooms but facilities and services like meeting rooms, toilets, etc which gives rise to ideas of territoriality so the users of one island do not cross to the other island for use of facilities and services, thus the mirrored part becomes like another floor, even less connected, as another floor is usually connected by several stairs while another part of a floor plan can be connected by only one link as we have seen in the sample. So architects are advised not to enlarge plans by symmetry. This is going to be explored further in part 4.6 of this chapter.

4.4 Ranking of functions in research laboratories according to mean integration values of collected functions:

Table 4.4.1 looks at the mean integration of collected individual functions of the same name of every research centre and in the end evaluate the research centre according to the order of integration of its functions. This applies to the 14 research centres. According to the activities that take place in a research centre, from contemplative activities such as sitting, writing to practical activities such as working at the laboratory bench, which usually involves a certain degree of local movement to interactive activities such as conversing or taking part in discussions to non-local movement as linear large scale movement.[22] The building with a better design should have its collective spaces – where a large number of users meet like a café, for example, coincides with the most integrated space while the individual cells like the offices where privacy and quietness is needed, coincide with the most segregated spaces. This is the proper integration order for functions of a research centre:

Collective space (café, restaurant, coffee room, lounge) >

Circulation spaces (corridors/ lobbies)>

Break out areas >

Meeting Spaces (meeting rooms/ conference rooms)>

Laboratories>

Offices

[22] Mentioned in Chapter One, p. 261.

By examining the **NRC** row it can be noticed that the most integrated spaces are the corridors which are very long, followed by the library, archives and auditorium, followed by the lobbies, followed by the laboratories. Spaces like the photocopying rooms are much segregated in the floor. Offices are the most segregated spaces in the whole floor which is good but they are also very deep as they are entered only through the laboratories. Their most integrated spaces are the corridors which are not collective spaces and they should be quiet as they are very close to where scientists work so they are not spaces for interaction to take place in. There aren't any other spaces for that too. So in the researcher's opinion the NRC is not a good plan for the promotion of interaction among scientists neither in terms of the presence of collective spaces nor in terms of integration values of the different functions in the floor.

By examining the **HBRC** row, we will find that the most integrated space is a connecting lobby, which means that a lot of interaction will take place in this space which is good because it is a large space and near the lift lobby where a lot of movement takes place. This is followed by corridors which is followed is followed by the library followed by the labs, offices, lifts and showroom all having the same integration value. The last items in the rank of integration are the collective spaces which are the dining spaces, which means that if the dining room is full of people nobody will notice as it is tucked away in a very segregated space. This design goes very much with the Egyptian attitude towards food and drink in public organisations. So instead of the dining spaces- as they are collective spaces in the HBRC plan- being the most segregated spaces in the floor, they should become the most integrated spaces in the floor and the researcher suggests converting the courtyard on the ground floor into a café for researchers and leaving the dining spaces on the first floor for workers.

By examining the **GIF** row, it consists of several laboratory wings which are totally separated and many of them are the result of accretion and not proper architectural solutions.

By examining the **IGER** row, the main corridors are the most integrated spaces, followed by the main lobby, from which the meeting area is visible but segregated to gain quietness and privacy but it is visible from the most integrated spaces. The meeting rooms follow in integration. Offices are much integrated for their functions and are facing the atrium so scientists overlook each other in the offices. It would have been better if the labs were exchanged for the offices as it is more interesting if scientists overlooked each other in their labs in order to promote communication. The lifts come down the list in integration, in fact, they are hidden between the offices. The dean areas should have been placed in a much integrated areas leaving segregation for other functions.

By examining the **SCRC** row, the café is the most integrated space, followed by the two main corridors, followed by the break out areas and in the end come the labs, followed by offices. This means that the offices are the quietest spaces in the system which fits perfectly with their functions as spaces where contemplation should take place.

By examining the **CBL** row, the most integrated space is the coffee room and the most segregated spaces are the offices.

By examining the **IMS** row, the most integrated spaces are the main corridors followed by the atrium space or café. This should be a good space for achieving communication space, first because it is on the ground floor, the entrance floor, and because it is the most integrated space on the floor. This is followed by labs followed by offices, followed by the photocopying room followed by the laboratories.

By examining the **BSC** row, the central corridors are the most integrated, followed by the links between the three blocks, followed by the lift lobby, followed by the rest of the corridors. The break out spaces where a lot of communication is supposed to take place are in an integrating space which proves further the localism of the layout of the architectural plan. The labs follow in integration and meeting rooms are in the end of the ranking, followed by the offices and stairs and lifts. This floor plan spatially strengthens interdepartmental ties on the expense of global ties on the floor level. It could be compared to the NCNSRC floor plan where spatial systems and managerial decisions play a role in strengthening local ties. The difference between the two plans is that the BSC plan offers much more meeting facilities like meeting rooms and break out areas.

By examining the **SIBM** row, the most integrated space is the main corridor in the lab wing, followed by the lab support spaces, followed by little corridors, followed by the laboratories, followed by the lobbies and the offices come at the end of the list. The pavilion as a whole is not much in integrated compared to the whole plan, but once inside it, lounges are the most integrated, followed by the conference rooms, followed by the break out area and finally the administration spaces. This rank of integration shows that communication will not happen naturally, people have to move to the area of the 'stuck' pavilion. But because the pavilion plan is different on every floor it will encourage users to travel from one space to another to use the different facilities.

By examining the **RPRRC** row, the central corridor is the most integrated space, followed by other corridors, followed by the two mirrored coffee breaks and conferences and meeting rooms which means that users will be divided into two groups in the plan. Offices followed by labs come at the end of the list.

By examining the **KDNARI** row, the lift lobby space is the most integrated space and it is the most integrated space which means that this space works as a good collective space while the lounge where the refreshments are served is in a more segregated space, so it will be a much quieter space. The corridors are very integrated in the floor which means a lot of interaction can take place in them. The **KDNARI** labs are much more integrated than the offices at the back which serves perfectly for their purposes.

By examining the **STRC** row, corridors are the most integrated spaces, followed by lobbies, followed by laboratories, followed by lab support spaces, followed by lounge, followed by lifts and stairs and side entrance.

The arrangement is good except for the lounge which should have been in a more integrated position.

By examining the **BYRC** row, the most integrated spaces are the corridors followed by the offices, followed by lounge, followed by labs, followed by lift lobbies, followed by lab support spaces and finally by stairs, toilets and lifts.

According to the ranking criteria on page 340, the research laboratories can be ranked as follows :

1) SCRC
2) CBL
3) IMS
4) RPRRC
5) IGER

The rest of the centres do not fit with the ranking criteria.

4.5 Justified Permeability Graphs

Before starting to analyse the justified permeability graphs of the different typical floors of the research centres, a summary of the justified permeability graphs will be introduced:

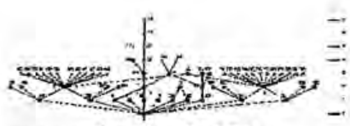
4.5.1 Summary of Justified Permeability Graphs

NRC

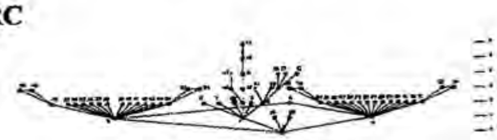
mean depth: 3.23

mean depth: 4.62

HBRC



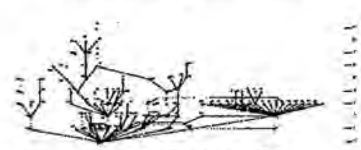
mean depth: 2.629



mean depth: 2.338

GIF

mean depth: 3.5



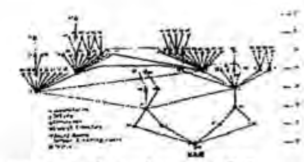
mean depth: 3.28

NCNSRC

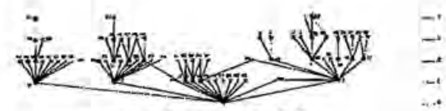
mean depth: 3.44

mean depth: 1.23

IGER

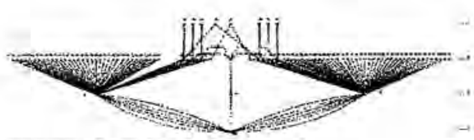


mean depth: 4.485

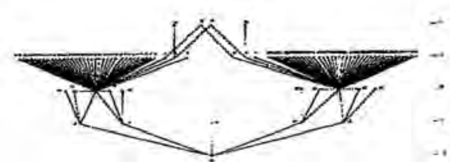


mean depth: 2.16

SCRC

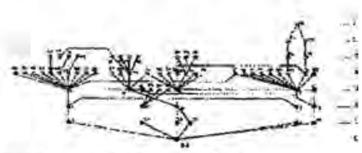


mean depth: 2.07

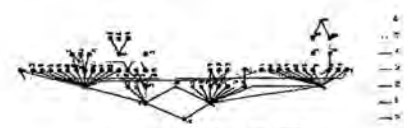


mean depth: 3.01

CBL



mean depth: 2.89



mean depth: 2.69

IMS

mean depth: 4.28

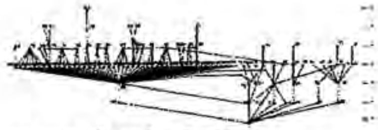
mean depth: 3.311

BSC

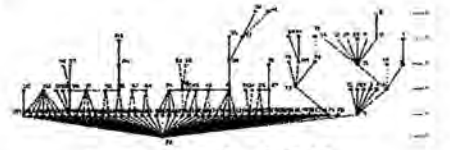
mean depth: 4.01

mean depth: 3.136

SIBM

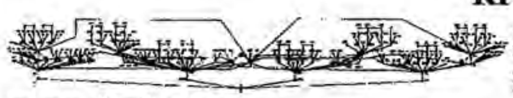


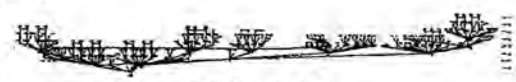
mean depth: 2.955



mean depth: 1.849

RPRRC

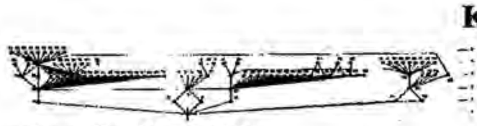


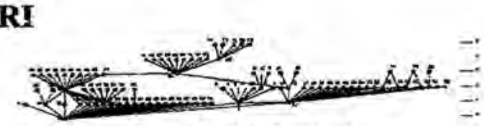


mean depth: 4.55

mean depth: 3.15

KDNARI

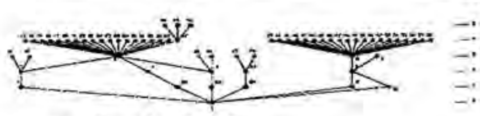


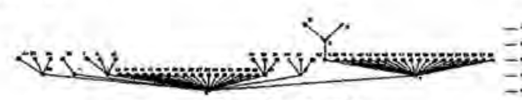


mean depth: 3.308

mean depth: 2.308

STRC

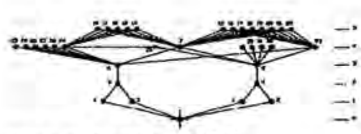


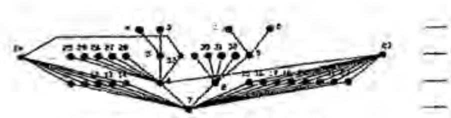


mean depth: 3.45

mean depth: 1.66

BYRC





mean depth: 3.96

mean depth: 1.667

4.5.2 Analyses of Justified Permeability Graphs

If the mean depth for JPG drawn from exterior is divided by the mean depth of JPG drawn from the most integrated space, a shallowness or deepening factor can be deducted of that most integrated space. This factor is calculated in the following part. **Table 4.5.2.1** ranks the 14 research centres according to mean depth from exterior. The SCRC is the shallowest, followed by HBRC, followed by CBL, followed by SIBM, followed by NRC, followed by KDNARI, followed by NCNSRC, followed by STRC, followed by GIF, followed by BYRC, followed by BSC, followed by IMS, followed by IGER followed by RPRRC. **Table 4.5.2.2** represents mean depths of the different laboratory floors drawn from the exterior and the mean depth of the floors drawn from the most integrated spaces and the corresponding shallowness factor arranged in an ascending order of the shallowness factor. **Table 4.5.2.3** ranks the research centres according to the strength of the shallowness factor of the most integrated space in every centre. As can be noticed from the table, the NCNSRC is the best in terms of difference between shallowness from exterior to shallowness from most integrated space, followed by BYRC, followed by STRC and so on.

Research Centre	Mean Depth of JPG drawn from exterior
SCRC	2.07
HBRC	2.629
CBL	2.89
SIBM	2.955
NRC	3.23
KDNARI	3.308
NCNSRC	3.44
STRC	3.45
GIF	3.5
BYRC	3.96
BSC	4.01
IMS	4.28
IGER	4.485
RPRRC	4.55

Table 4.5.2.1 Research centres arranged in an ascending order of mean depth from exterior.

Research Centre	**Mean Depth of JPG drawn from exterior**	**Mean Depth of JPG drawn from most integrated space**	**Shallowness Factor**[23]
SCRC	**2.07**	**3.01**	**.68**
HBRC	**2.629**	**2.338**	**1.124**
CBL	**2.89**	**2.69**	**1.074**
SIBM	**2.955**	**1.849**	**1.598**
NRC	**3.23**	**4.62**	**.699**
KDNARI	**3.308**	**2.308**	**1.433**
NCNSRC	**3.44**	**1.23**	**2.796**
STRC	**3.45**	**1.66**	**2.078**
GIF	**3.5**	**3.28**	**1.06**
BYRC	**3.96**	**1.667**	**2.375**
BSC	**4.01**	**3.136**	**1.278**
IMS	**4.28**	**3.311**	**1.29**
IGER	**4.485**	**2.16**	**2.076**
RPRRC	**4.55**	**3.15**	**1.44**

Table 4.5.2.2 ranks the research centres according to shallowness from the most integrated space

By examining **table 4.5.2.2**, the SCRC and NRC are the only two plans with the shallowness factor less than 1 as they are shallower from the exterior than from the most integrated space, because the SCRC plan has many entrances and the NRC plan has the highest number of stairs and lifts. As for the rest of

[23] This factor shows how the most integrated space can reduce the mean depth of the system from that point.

research centres combining the presence or absence of facilities that aid in communication and some of the spatial qualities that generate movement and social knowledge or conserve movement and social knowledge and thus affect the flow of science among researchers and thus its progress.

Chapter Five

Summary, Conclusions and Recommendations 367-373

5.1	Summary	367
5.2	Conclusions	368
5.3	Recommendations	369-373

5.1 Summary

Unlike other building types, research laboratories entail a paradox in their design logic which attempts to create a balance between two variables that of quietness needed for scientists to contemplate and write their ideas without interruption and yet simultaneously the co-presence of others needed for the random communication and consultation that helps in problem solving and the flow of technology.

The fundamental fact of a research laboratory building is that as much as being written that scientists work in many places, and not behind the laboratory bench still each inhabitant is mainly located where his or her laboratory or office is located. That is why in this thesis the study was applied on the typical floor level.

This thesis attempted to pin down the structure by which research laboratories in general work as building types. This was done through the literature review of research centres as building types and through the analyses of 14 international research centres: Five Egyptian, three British, three American and three Japanese. It architecturally reviewed the facilities each research centre contained and ranked the laboratories accordingly. It also examined spatial variables like integration, intelligibility and depth of each research centre according to the space syntax theory and ranked the laboratories accordingly. The higher the mean integration value of a floor the higher communication it would predict to occur in it. The higher intelligibility value, the less inhabitants and visitors would get lost or disoriented in it.

5.2 Conclusions:

After thoroughly examining the national and international samples the following conclusions can be made:

5.2.1 The Egyptian sample lacked informal collective spaces, meaning that it ignored informal interaction of inhabitants.

5.2.2 2/3 of the British research centres sample contained collective spaces like a central café and 1/3 had a coffee break on every floor.

5.2.3 The American research laboratories sample consisted of large floors. 2/3 of American sample included collective spaces on the scale of the floor while others included collective spaces on the scale of the building.

5.2.4 The Japanese research centres sample consisted of moderate floors and consistently separate general facilities from laboratory wings and connect them through links and bridges. The laboratories included collective spaces for floor users and for the whole building.

5.2.5 Repeating or mirroring part of the plan, which is a common practice of architects till his day, without well linking them, reduces the mean integration of the plan by dividing it into sections that act as another floor plan, even less connected and thus communication is reduced between the inhabitants of the plan.

5.2.6 Symmetry of plans divides users as it duplicates services, toilets and thus divides the floor into islands which encourages territorial behaviour and also users of one island do not usually cross to the other islands as they have got the same functions in their islands. This segregates the plan even more than dividing it into separate floors as floors get connected by more than a staircase because of specifications and safety rules, while islands or wings on the same floor can get linked by only one bridge.

5.2.7 Some of the collective spaces in the samples like cafes are not placed in integrated spaces and instead tucked away in less integrated spaces, this means that they will not achieve their functions in attracting users. They are supposed to be 'hives of social activities' at lunch time so they should be placed in the most integrated spaces in research centres. These social contacts can then be transported to the laboratories.

5.2.8 The larger the plan of a research laboratory/ organisation the more difficult it is to integrate it.

5.2.9 Consequently, the smaller the plan the easier to integrate it and the easier for users to meet and have social relations.

5.2.10 The central café plays an important role in integrating staff than would a coffee break on every floor.

5.3 Recommendations

5.3.1 Planning Recommendations

5.3.1.1 Site plans should be designed with promotion of communication among users of all buildings in mind. Buildings should have a centre for global communication and not be haphazardly scattered along a site.

5.3.1.2 Restaurants or cafes should be carefully planted around sites of research laboratories.

5.3.2 Architectural Recommendations

5.3.2.1 In order to attract the best researchers state of the art research laboratories need to designed and built. In order to encourage researchers to stay and work late better facilities should be available on site. Research laboratories sites should compete to offer their staff better services like nurseries, restaurants, cafes, cinemas, post services, repair shops, etc. This would attract them to stay and work for more hours and relieve them from the every day worries that can keep them from concentrating on their scientific achievements.

5.3.2.2 Research laboratory buildings should not be tall buildings as the increase in the number of floors will result in the decrease of chances of encounters among users of different floors.

5.3.2.3 Simplicity of the plan is the key of a well communicating research centre with central stairs and lifts.

5.3.2.4 The use of escalators instead of stairs and lifts could turn the process of transport into a celebration of movement and communication.

5.3.2.5 The use of glass partitions is recommended for laboratories as they increase visibility and thus the transfer of knowledge in the same organisation.

5.3.2.6 Researchers should be discouraged to eat and drink in their labs and offices. There should be a large collective space designated for food and drink. It should be able to receive all the users of the building within the lunch hour. This hour should be a celebration of global communication among the whole staff of the research centre. This solution is much recommended than coffee rooms situated on every floor as the latter strengthens local or departmental ties on the expense of global ties, while the former can achieve both depending on the desire of the people to socialise.

5.3.2.7 Collective spaces like cafes and lounges should be placed in the most integrated space in the building and in the floor where it is situated. If the research centre is a tall building, then it should be placed in mid floors where it can be equidistantly reached by most inhabitants at lunch time.

5.3.2.8 Well integrated plans with good long visibility lines, with one central battery of stairs and lifts provide a good solution for plans of research centres as inhabitants get chances to meet other inhabitants on the same floor frequently and also inhabitants of different floors get chances to meet through the central lifts and escalators or staircases.

5.3.2.9 The working hours in Egypt which are good six hours (9am – 3pm) can allow a half hour for lunch and socialisation.

5.3.3 *Spatial Recommendations:*

5.3.3.1 Well connected unsymmetrical plans are arguably better in promoting communication among their users. Mirroring of wings and repetition of parts are highly not recommended as architectural solutions for enlarging the plan.

5.3.3.2 Collective spaces that help in promoting communication should be placed in the most integrated spots in the floor plan.

5.3.3.3 Functions that need privacy and quietness like research offices should be placed in segregated spaces hidden away from attractor functions like photocopying rooms, meeting rooms, toilets, etc.

5.3.3.4 For achieving better communication among users of different floors, small plans is the solution. For with small plans, central lifts and stairs can be satisfactory and thus inhabitants can bump into each other in lifts or staircases. On the other hand, in large plans many lifts and fire exits would be necessary to meet safety specifications. In that way communication would be reduced as inhabitants will tend to use the lifts and stairs nearest to them.

5.3.3.5 Theoretically speaking, the best communication can be achieved through a single floor building as all staff will be available for communication.

5.3.4 *Managerial Recommendations:*

Managerial decisions are the most sensitive as they can overrule any randomness suggested by the plan of the building. The management should be aware of the following:

5.3.4.1 The strengthening of global communication of inhabitants of a research centre in order to achieve globally oriented research rather than strengthening interdepartmental ties and thus achieving localised research.

5.3.4.2 Daily, weekly and monthly formal and informal meetings on all levels should be encouraged. Even if meeting rooms are not available, meetings should take place in research offices or laboratories.

5.3.4.3 There should be a specified lunch hour where researchers take a break and meet and resume work afterwards.

5.3.4.4 Overcrowding of laboratories and offices should be avoided.

5.3.5 Social Recommendations:

5.3.5.1 Social rules governing the use of research centres should change and work on the omission of the guilty feeling associated with socialising, on behalf of the researchers, but on the contrary, this attitude should be encouraged and the practice of global communication facilitated rather than the prevailing local communication.

5.3.5.2 Disclosed behaviour on behalf of researchers like closing doors, blinds and covering glass partitions should be discouraged. Visibility remains a key for the flow of technology and for better communication.

5.3.6 Research Recommendations:

5.3.6.1 Further research can be implemented on research centres by visiting buildings and making observations and correlating them with spatial variables. This proved difficult at the present research because of the nature of research in general where research buildings are inhabited mainly by inhabitants, and visitors like the researcher tend to disturb the pattern of behaviour. It was also difficult to make observations of labs and offices when doors were closed.

5.3.6.2 It was difficult to visit international research centres due to the classification of research in general and due to the geographical barrier for international centres.

5.3.6.3 Global spatial analysis including all plans is recommended for all research centres. But for proper comparison all plans need to be available.

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374 - 377

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English and Arabic Summary

378 - 380

Research has shown that consultation with colleagues from inside and especially outside the research group of the same organisation can have a profound effect on the quality of problem solving. This notion when translated to research and architecture means that better research centres are the ones that promote communication among their inhabitants. Some of the factors that apply here are managerial decisions that govern the process of communication and the layout of the architectural plan of research centres.

This thesis tried to pin down the way the architectural plan can affect communication among users. Chapter one reviewed the literature concerning research centres. Chapter two introduced the space syntax theory which was developed in UCL in the 1970s which is used in the spatial analysis of buildings and urban areas. It introduced the techniques used in the analyses. Chapter three architecturally reviewed the 14 research centres; 5 Egyptian, 3 British, 3 American and 3 Japanese and pointed out the advantages and disadvantages of each centre. It also produced a scoring table in which research centres were ranked according to the availability of facilities that promote communication among users I each centre. Chapter four spatially analysed the 14 research centres in an attempt to pin down how the layout of the architectural plan can influence the way space is used and how space configuration affects communication. It zoomed on important qualities that theoretically promote communication like integration, depth and intelligibility and ranked the research centres accordingly. It examined justified permeability graphs from the exterior of the plan and compared them to justified permeability graphs drawn from the most integrated parts of the plans in order to compare depth of the different floors of research centres. Finally it ranked research centres according to those factors combined.

Chapter Five summarised the findings of the thesis, drew conclusions and recommendations of all kinds: Planning, architectural, spatial, managerial, social and research recommendations.

الملخص العربي

أثبتت بعض الأبحاث الأمريكية في الدراسات المعنوية أن الاستشارات بين الباحثين من داخل المؤسسة البحثية تحدث تأثيرا ايجابيا على المنتج البحثي وبالخصوص حين تكون الاستشارات مع أشخاص خارج المجموعة البحثية للباحث قد تعطى أبعادا أفضل للبحث. وبالتالي أفضل طريقة لتحقيق ذلك تكون باستشارة زملاء من داخل المركز البحثي لتفادى خروج أسرار العمل إلى الخارج. في ضوء هذه الدراسة يجب أن تساعد مراكز الأبحاث على زيادة الاتصالات بين الباحثين وذلك دور قد يلعبه تصميم المركز البحثي.

تعرض الفصل الأول من هذه الرسالة للكتابات التي كتبت عن مراكز الأبحاث بالنقد والتحليل. استعرض الفصل الثاني نظرية تركب الفراغات (Space Syntax Theory) والتي تم إرساؤها في جامعة لندن في السبعينات والتي يمكن تطبيقها في التحليل الفراغي للمباني والفراغات الحضارية. كذلك تم استعراض الأدوات التي سوف تستخدم في التحليل الفراغي. استعرض الفصل الثالث المراكز البحثية المختارة معماريا واستخلص مميزات وعيوب التصميم المعماري لكل مركز وكذلك تم عمل ترتيب لتلك المراكز بناء علي احتوائها علي عناصر تساعد علي الاتصالات بين الباحثين. تناول الفصل الرابع هذه المراكز البحثية بالتحليل الفراغي للمساقط الأفقية واهتم بعوامل مهمة مثل التجميع (Integration) وعامل العكسى للعمق(Shallowness factor) و فهم الفراغ (Intelligibility) وتم عمل تقييم لتلك المراكز البحثية بالنسبة لتلك العوامل الفراغية التي استنتجت من الفصل الرابع والعوامل المعمارية التي استنتجت من الفصل الثالث والتي تؤثر علي الاتصالات بين الباحثين داخل تلك المراكز. يلخص الفصل الخامس ما تم عمله في الرسالة ويحدد النتائج التي تم التوصل إليها وكذلك التوصيات، وتنوعت التوصيات من تخطيطية، معمارية، فراغية، إدارية، اجتماعية وبحثية.

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