Architectural Behaviorology for Durability by Actor Network Drawing
Reader

Chair of Architectural Behaviorology
BUK
Master Thesis HS21

CONTENTS

ARCHITECTURAL BEHAVIOROLOGY FOR DURABILITY BY ACTOR NETWORK DRAWING

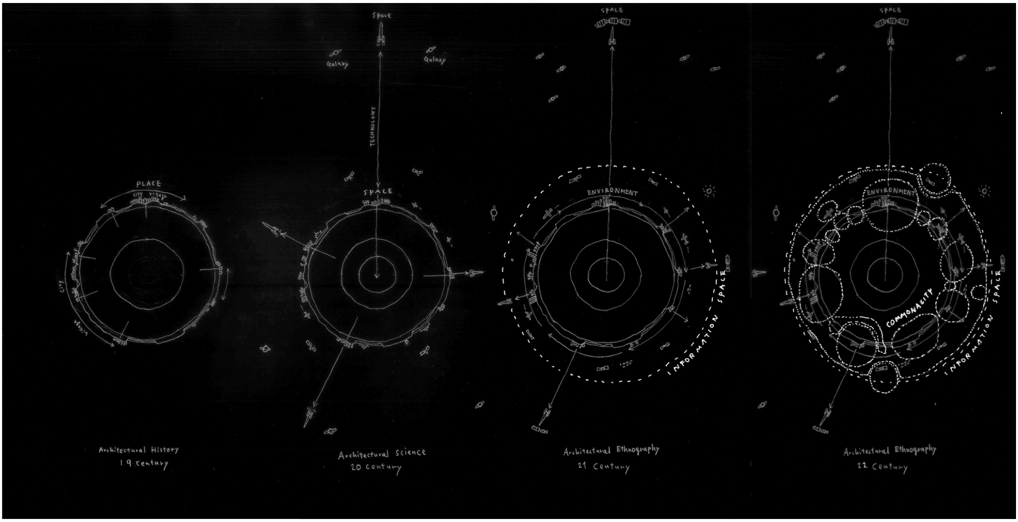

Fig. 01: Architectural Ethnography Drawing version 5 (Momoyo Kaijima, 2021)

Architectural Behaviorology being a design theory and methodology that we have adopted with the objective of rediscovering the forgotten values of resources through the lens of ethnography. In essence it tries to find existing barriers and deficits and then challenge them in order to create better accessibilities to local resources. The aim is to activate the behaviors of actors, both human and resource, to create urban-rural commons and rejuvenate community livelihoods with small-scale primary industries.

In our master thesis studio for challenge of “Durability” as main theme proposed by Elli Mosayebi, the each student could apply an topic and a site area for architectural design research through the method of Architectural Behaviolorolgy with the actor-network drawings collaborated in BUK.

Studio will be take on Monday each week. In Preparation phase (W1-7) students will focus on finding the actors around the site area and explain the actor network drawing and also do an individual research on a constructive theme including 1. typology of a constructive system, 2. A constructive analysis in scale 1:10 of a contemporary building of this constructive system.

In Elaboration Phase(W8-16) students will focus on design the architectural intervention in the site are to create the new relationship between actors for durability of the area with a final deliverable of a 1:10 detail of their design supported by construction knowledge.

SCHEDULE

	Date	D-arch Program Program	D-arch Grading	Studio Program Schedule
Week 1	Mon 20.09.	Hand-out of Master Program		17:00 - 19:00 Orientation - Theme discussion
Week 2	Mon 27.09.			Desk Critic
Week 3	Mon 04.10.			1ST MID REVIEW
Week 4	Mon 11.10.			Desk Critic
Week 5	Mon 18.10.		40 %	Desk Critic
Week 6	Mon 25.10.			SEMINAR WEEK
Week 7	Mon 01.11.			2ND MID REVIEW
Week 8	Mon 08.11.	End of Preparation Phase Start of Elaboration Phase		Desk Critic
Week 9	Mon 15.11.	November: Decision whether students continue or interrupt the Master Thesis		Desk Critic
Week 10	Mon 22.11.			Desk Critic
Week 11	Mon 29.11.		60 %	Desk Critic
Week 12	Mon 06.12.			3RD MID REVIEW
Week 13	Mon 13.12.			Desk Critic
Week 14	Mon 20.12.			Desk Critic

SCHEDULE

Content new	CAB 70% Deliverables	BUK 30% Deliverables	Grading
Studio Introduction	Presentation of topic and site by students		
Site Analysis Image of the place	Area Actor Network Drawing (AND) draft		
	Area AND)	Constructive analysis in scale 1:10	10 %
Site Analysis Image of the place	Area AND		
Site Analysis Image of the place	Area AND	(Option Desk Critic)	
			30 %
	Area AND	Constructive analysis	
Form, Structure	Plans, Sections, Elevations Modell (1:50)		
Form, Structure	Plans, Sections, Elevations Modell (1:50)		
Form, Structure	Plans, Sections, Elevations Modell (1:50)	Detail 1:10	30 %
Form, Structure, Detail	Plans, Sections, Elevations Detail (1:20) Modell (1:50)		
	Project AND with Area AND Modell (1:50)	Detail 1:10	
Production of final hand-in	Project AND with Area AND Modell (1:50)	(Option Detail 1:10)	
Production of final hand-in	Project AND with Area AND Modell (1:50)		

SCHEDULE

		D-arch Program		Studio Program
	Date	Program	D-arch Grading	Schedule
Week 15	Mon 27.12.			CHRISTMAS HOLIDAYS
Week 16	Mon 03.01.			Desk Critic
Week 17	Mon 10.01.	Submission of Master Thesis 13.01.2022		**HAND-IN 13.01.2022**
Week 18	Mon 17.01.			FINAL REVIEW
Week 19	Mon 24.01.	Notenkonferenz 24.01.2022		KRITIK MASTERARBEITEN 24.01.2022

SCHEDULE

	CAB 70%	BUK 30%	
Content new	Deliverables	Deliverables	Grading
Production of final hand-in	Project AND with Area AND Modell (1:50)		30 %
	Project AND with Area AND Modell (1:50)	Detail 1:10	

PRACTICAL INFO AND SUBMISSION GUIDELINES

Teaching formats

The Review and critics will be on every Monday. At first day we will start with the topic and site presentation by the students. And from 2nd week, the desk critics will be set.

Preparation phase in key-words:

Chair of Architectural Behaviorology

- **Actor-Network Drawing**
- Architectural Behaviorology
- **Construction**
- Durability

BUK

- Individual research and analysis of an existing constructive system
- Thesis: Durability of that building structure in regard of materiality and construction
- Documentation drawing in scale 1/10 of one constructive loci: plinth, wall, opening, roof

Elaboration phase in key-words:

Chair of Architectural Behaviorology

- Actor-Network Drawing
- **Architectural Behaviorology**
- Construction
- **Durability**

BUK

- Isometric drawing in scale 1/10 of a construction detail of the design

Grading ratios

Preparation phase:	40% (First mid review 10%, 2nd mid review 30%)
Percentage Partner 1/ CAB:	70%
Percentage Partner 2/ BUK:	30%
Elaboration phase:	60%(3rd mid review 30%, Final review 30%)
Percentage Partner 1/ CAB:	70%
Percentage Partner 2/ BUK:	30%
Number of Credits:	30 ECTS

Contact

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Basil Witt witt@arch.ethz.ch

BUK
HIL E45.2
Margit Pschorn pschorn@arch.ethz.ch

PRACTICAL INFO AND SUBMISSION GUIDELINES

For Mid Reviews and the Final Review we ask you to submit all the data of your project on the Polybox, following the guidelines here below.

Filenames

- Please name all files in the following format:

- Please name all files in the following format:
"YYMMDD_HS21_Event_Surname Name_Description.pdf"
Date of hand-in: YYMMDD (Year, Month, Day) For example 15th of March 2021 --> 210315
Letter code of the semester: HS21
Event: Mid Review 1, Mid Review 2, Final Review
Name: Surname Name
Description: Actor Network, Model, Plan, etc.

Example: 201012_HS21_Mid Review 1_Muster Max_Actor Network.pdf
Example: 201116_HS21_Mid Review 2_Example Eveline_Modellphoto 1.jpg

Access to Server

You will find further information and references in the Student Server of the BUK chair, accessible at the following paths:

smb://nas22.ethz.ch/arch_iea_buk_diploma

NOTE: if you want to access the server from home or from other locations outside the university you need to use a VPN connection.

Access to Polybox
You will submit all the data (CAB and BUK) on the Polybox, accessible at the following link:

https://polybox.ethz.ch/index.php/login

Submission deadlines

The deadline is on Thursday, 13th of January 2022.
All drawings, model photos etc have to be submitted on time. Submission deadlines have to be kept. If out of technical reasons, a submission cannot be done, please contact the assistant before submission deadline.

GRADING AND EVALUATION SHEET

Grading | Diploma - Chair of Architectural Behaviorolgy | HS 2021

Student:				Date:					
Partner 1:	Momoyo Kaijima / Basil Witt								
Partner 2:	BUK Dozentur Mettler, Studer / Margit Pschorn								

					Maximal Points	Student: Points	Grade	Total	Studio Average
70%		**Partner 1**	**CAB**						
		Hand in	Critera						
	PREPARATION 40%	1st Crit (10%)	Submission		4.00	0.00			
				Understanding method Arch. Behaviorology	0.40	0.00			
				Research	0.40	0.00			
				Design	0.40	0.00			
				Visualisation	0.40	0.00			
				Structure and Material	0.40	0.00			
			Submission delay		-0.25	0.00	0.00	0.00	0.00
		2nd Crit (30%)	Submission		4.00	0.00			
				Understanding method Arch. Behaviorology	0.40	0.00			
				Research	0.40	0.00			
				Design	0.40	0.00			
				Visualisation	0.40	0.00			
				Structure and Material	0.40	0.00			
			Submission delay		-0.25	0.00	0.00	0.00	0.00
	ELABORATION 60%	3rd Crit (30%)	Submission		4.00	0.00			
				Understanding method Arch. Behaviorology	0.40	0.00			
				Research	0.40	0.00			
				Design	0.40	0.00			
				Visualisation	0.40	0.00			
				Structure and Material	0.40	0.00			
			Submission delay		-0.25	0.00	0.00	0.00	0.00
		Final hand-in (30%)	Submission		4.00	0.00			
				Understanding method Arch. Behaviorology	0.40	0.00			
				Research	0.40	0.00			
				Design	0.40	0.00			
				Visualisation	0.40	0.00			
				Structure and Material	0.40	0.00			
			Submission delay		Fail	0.00	0.00	0.00	0.00
		Final Grade Rounded Chair of Architectural Behaviorology						**0.00**	0.00
30%		**Partner 2**	**BUK**					**0.00**	
	PREPARATION 40%	1st Crit (10%)	Submission		4.00	0.00			
				Research of present constructions	0.40	0.00			
				Analysis of durability of choosen detail	0.40	0.00			
				Complexity of choosen detail	0.40	0.00			
				Understanding of building procedure	0.40	0.00			
				Visualisation of constructive elements	0.40	0.00			
			Submission delay		-0.25	0.00	0.00		
		2nd Crit (30%)	Submission		4.00	0.00			
				Research of present constructions	0.40	0.00			
				Analysis of durability of choosen detail	0.40	0.00			
				Complexity of choosen detail	0.40	0.00			
				Understanding of building procedure	0.40	0.00			
				Visualisation of constructive elements	0.40	0.00			
			Submission delay		-0.25	0.00	0.00		
	ELABORATION 60%	3rd Crit (30%)	Submission		4.00	0.00			
				Construction development as part of the design process	0.40	0.00			
				Understanding of building procedure	0.40	0.00			
				Visualisation of constructive elements	0.40	0.00			
				Quality of materials and connections	0.40	0.00			
				Relationship with current building culture	0.40	0.00			
			Submission delay		-0.25	0.00	0.00		
		Final hand-in (30%)	Submission		4.00	0.00			
				Construction development as part of the design process	0.40	0.00			
				Understanding of building procedure	0.40	0.00			
				Visualisation of constructive elements	0.40	0.00			
				Quality of materials and connections	0.40	0.00			
				Relationship with current building culture	0.40	0.00			
			Submission delay		-0.25	0.00	0.00		
		Final Grade Rounded BUK							
100%		**Final Grade Rounded**						**0.00**	

Absence:

Conclusion:

Student Signature:

With their signature, the student confirms to understand the above shown grading table and agrees to the statements formulated in the conculsion

GRADING AND EVALUATION SHEET

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Departement Architektur

BEURTEILUNGSBLATT

Master-Arbeit – Semester:

Diplomandin / Diplomand:

Professur (Partner 1):	Prof. Momoyo Kaijima
Professur (Partner 2):	Prof. Daniel Mettler/ Daniel Studer

DIPLOMA:

1. **Chair of Architectural Behaviorology** Project Description	
Understanding of Architectural Behaviorology	
Research	
Design	
Visualisation	
Structure and Material	

Note Chair of Architectural Behaviorology:

2. **BUK Bautechnologie und Konstruktion**	

Note BUK:

Von der Notenkonferenz beschlossene Note:

ACTOR NETWORK DRAWING REFERENCES

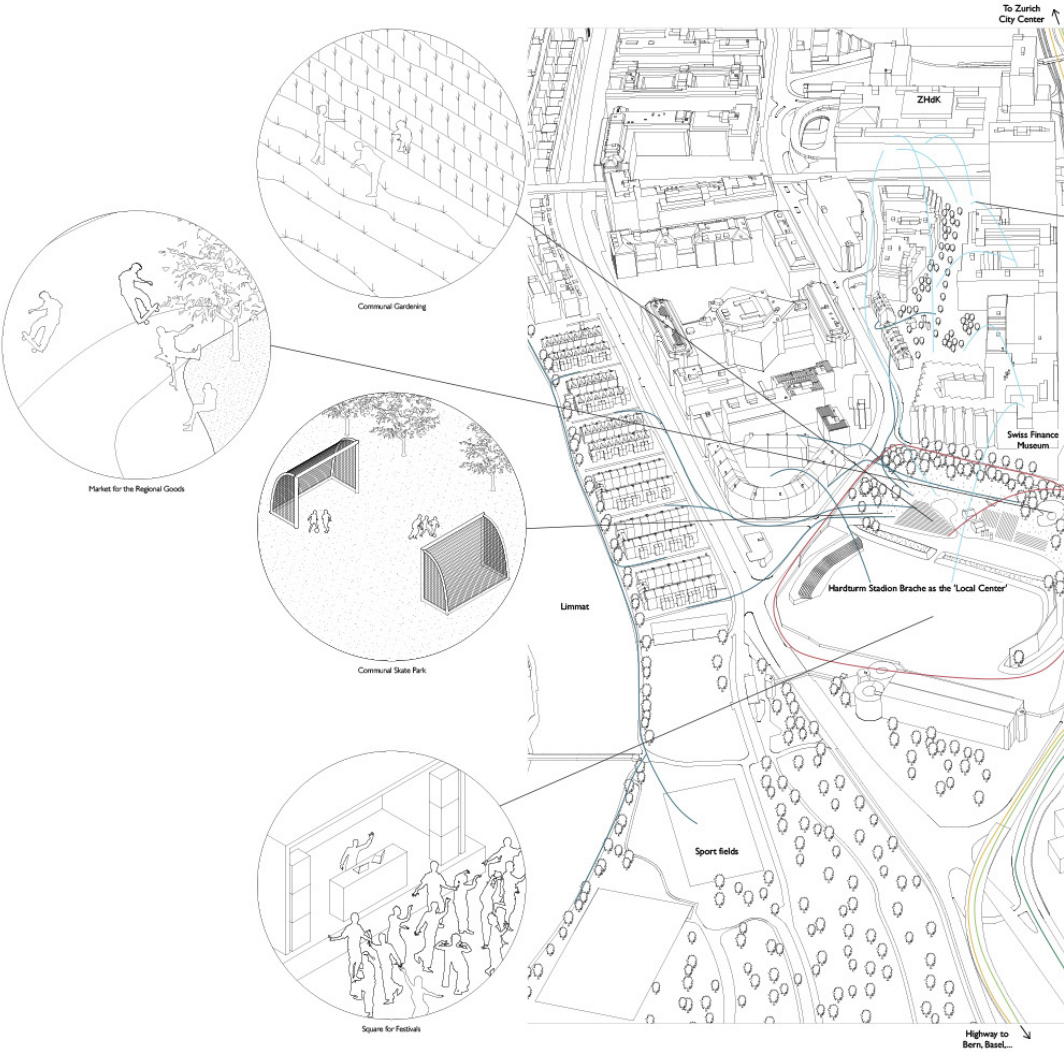
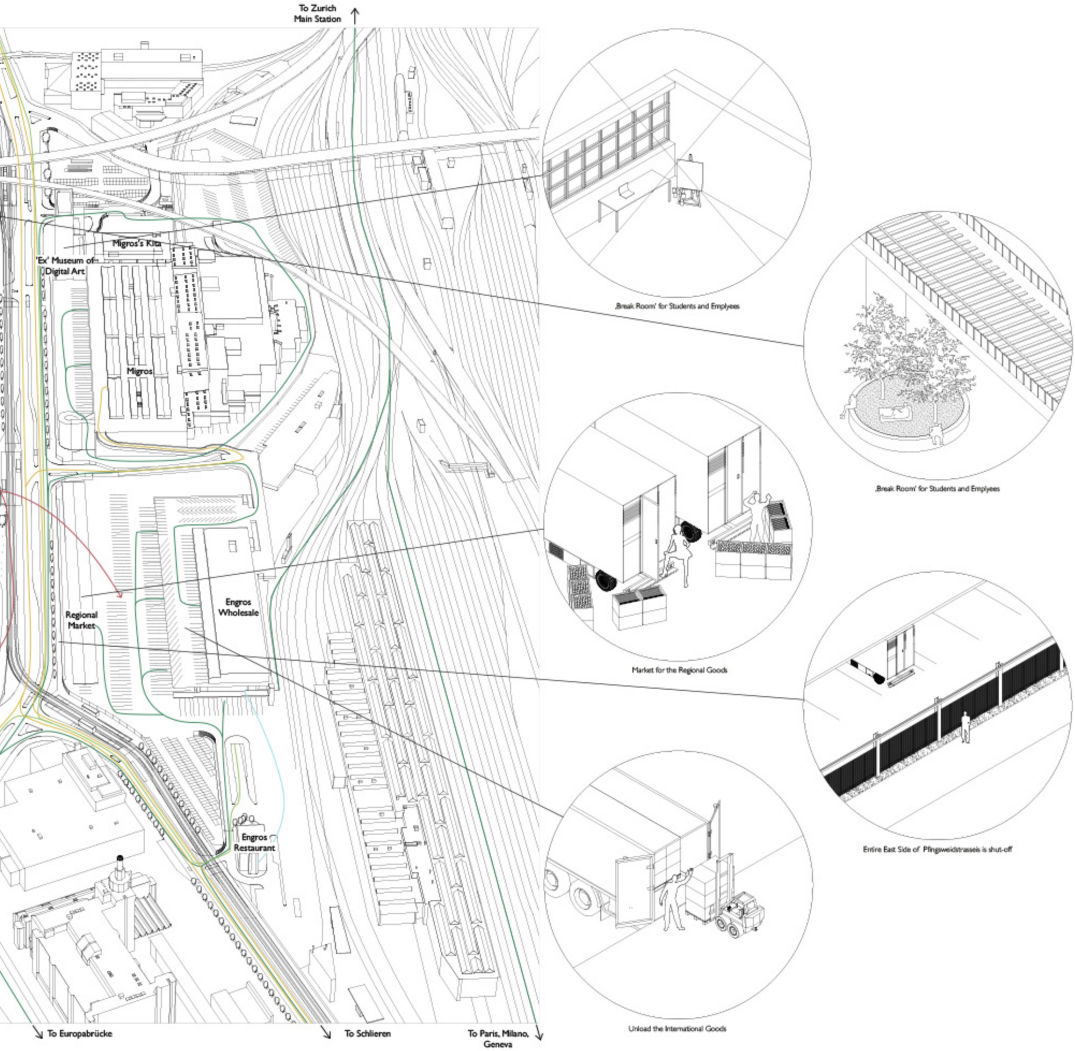


Fig. 02: Actor Network Drawing, Diploma FS21 24/7 Metropolitan Hybrid Machine (Oliver Brunhart, ETHZ)

ACTOR NETWORK DRAWING REFERENCES



ACTOR NETWORK DRAWING REFERENCES

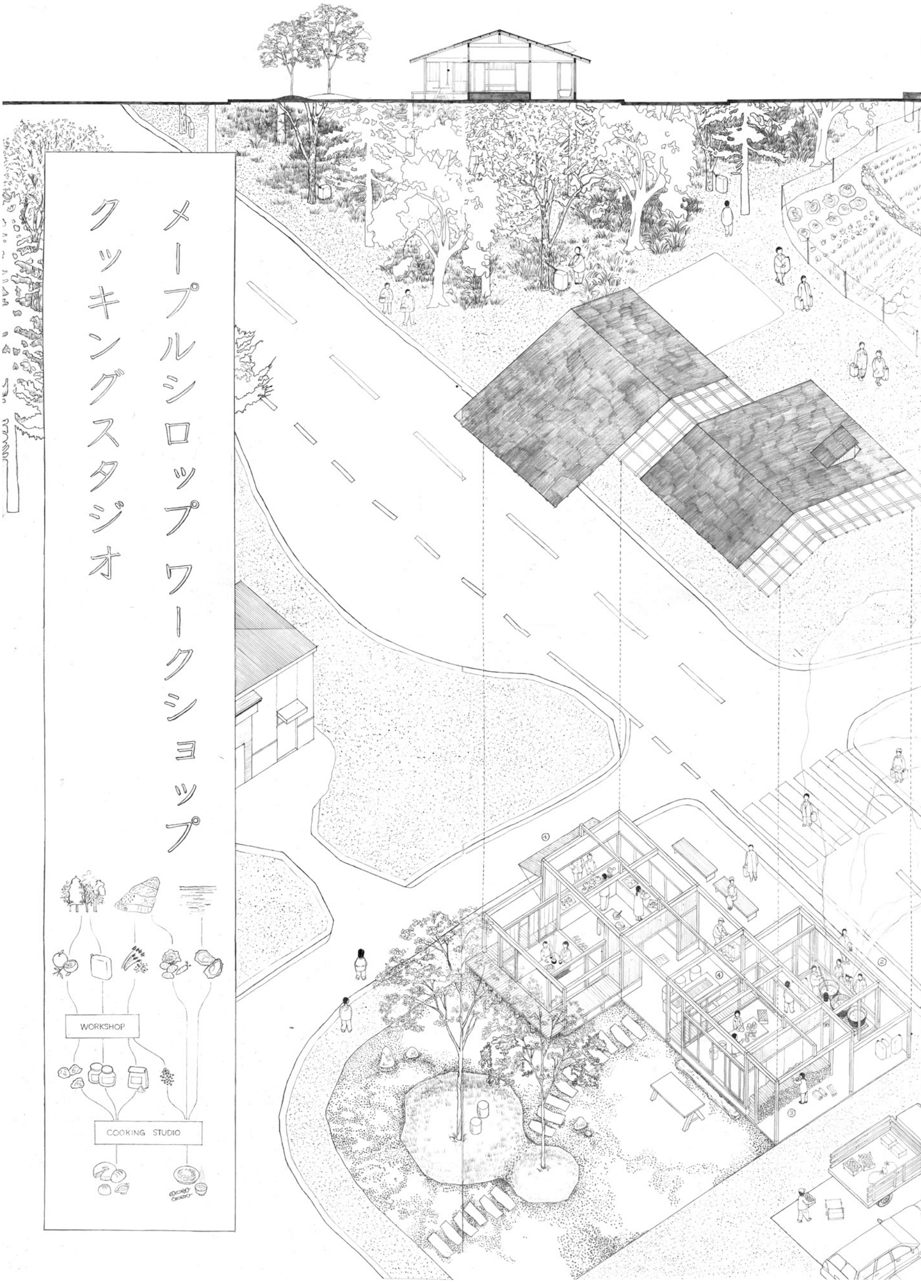
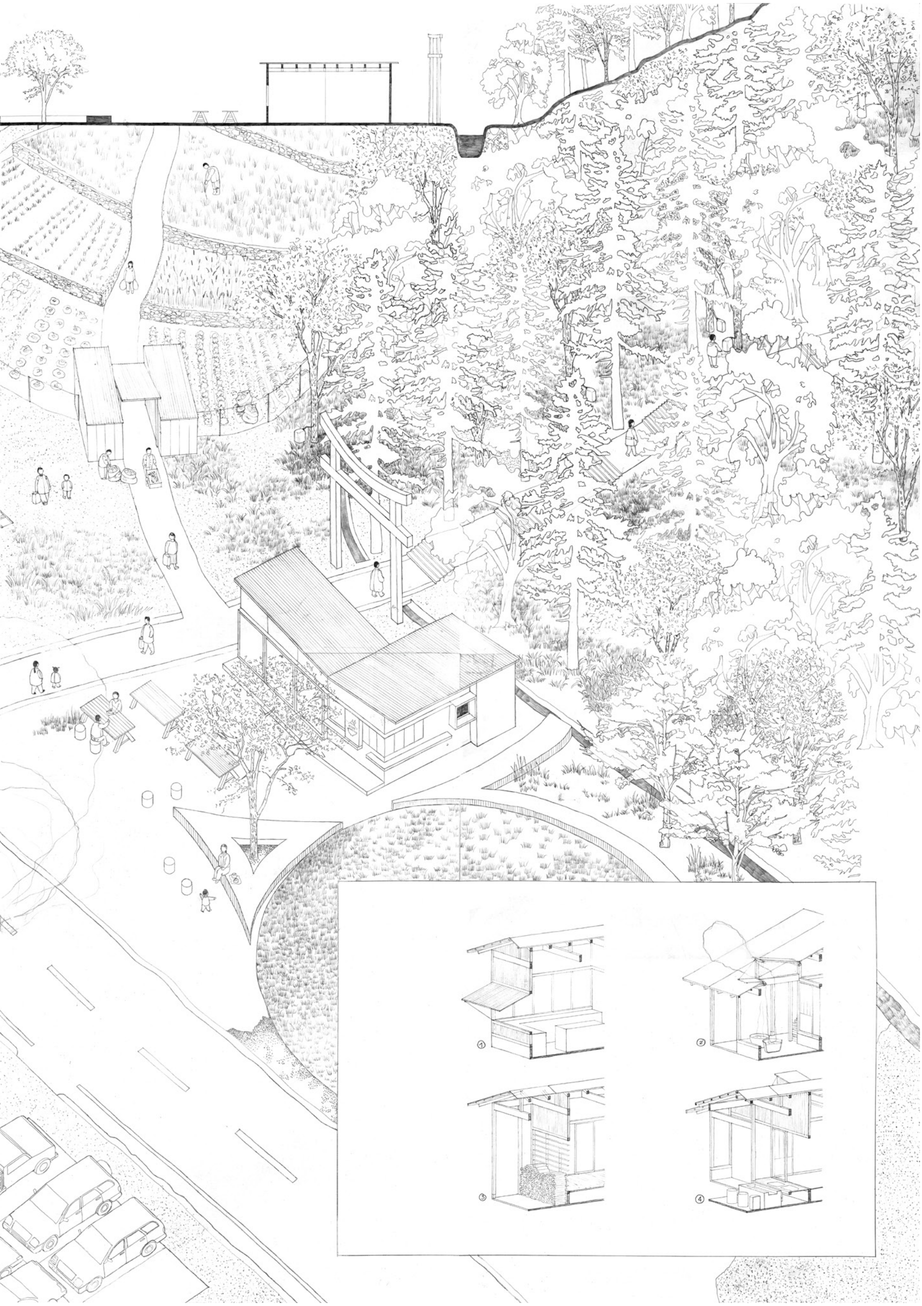


Fig. 03: Actor Network Drawing, HS19 (Yuni Zhao, ETHZ)



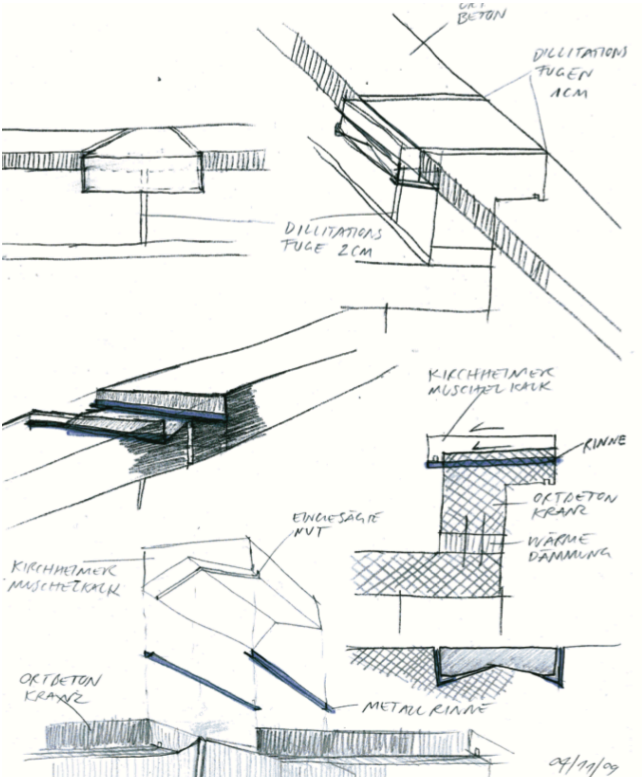
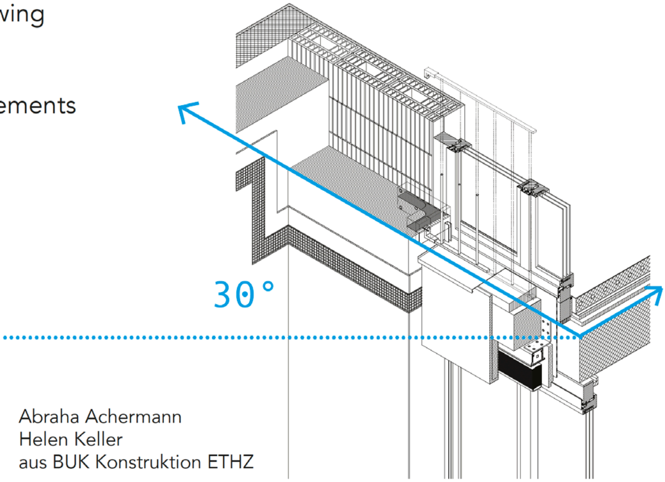


Fig. 04: The Drawing as a tool for controlling construction and expression during design process. It is directly linked to the design. (Käferstein & Meister Architekten, Haus in Küssnacht)

Isometric drawing

- 30°-angle
- true measurements readable

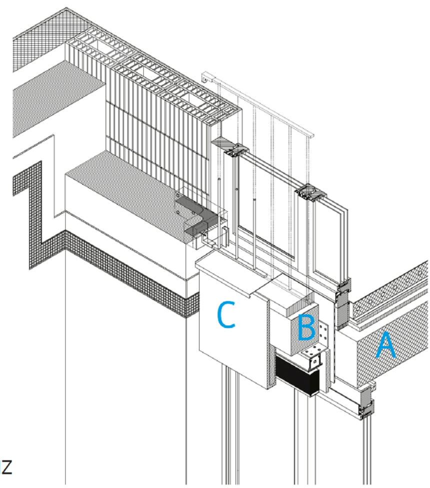


Abraha Achermann
Helen Keller
aus BUK Konstruktion ETHZ

Isometric drawing

- Building process is visible through layering

- Load bearing elements
- Insulation
- Sealing
- Protection / Covering

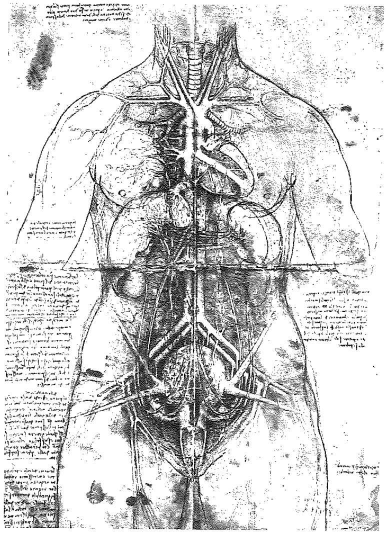


Abraha Achermann
Helen Keller
aus BUK Konstruktion ETHZ

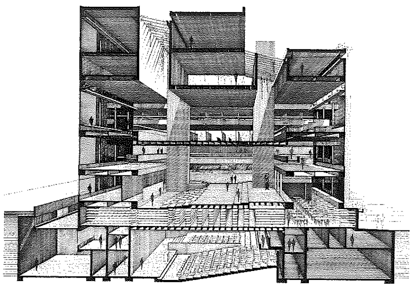
Fig. 05: Reference for an isometric drawing (BUK Konstruktion ETHZ)

Fig. 06: San Antonio Market, Barcelona, 1955 (theguardian.com)

READINGS



レオナルド・ダ・ヴィンチ　女性内臓図
Leonardo da Vinci, Principal Organs of a Woman



ポール・ルドルフ　イエール大学芸術・建築学部 *1
Paul Rudolph, Yale Art and Architecture Building

“GRAPHIC ANATOMY 2 ATELIER BOW-WOW”
Atelier Bow-Wow

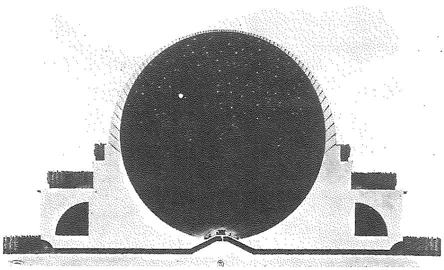
Leonardo da Vinci is known to have sketched dissections that he observed and conducted himself in order to better understand the internal structure of the human body and to draw livelier human figures. Inspired by such medical/artistic anatomical illustrations, we attempted to draw architectural anatomical illustrations. What resulted was *GRAPHIC ANATOMY ATELIER BOW-WOW*. A question that we are often asked in regard to these illustrations is: “In which phase do you make these drawings? During design? During construction, to give instructions to the site? Or after the project is completed?” Apparently, this practice of ours seems odd to the eyes of others.

What we refer to here as “illustrations” are detailed section and plan drawings to which we have given depth through the use of one-point perspective and added incidental details that include people, furniture, fixtures, plantings, vehicles, and buildings in the surroundings. Typically, detailed section and plan drawings are made for the purpose of holding meetings with contractors during the design or construction phases, while perspective drawings are drawn in order to convey the contents of a project proposed for construction to clients, local residents, or potential users. Both are made at a time anterior to the completion of the architectural construction in the interest of establishing better communication between the involved parties. By contrast, our illustrations depict in considerable detail the particulars of elements that can only be observed when an architectural construction is completed and it begins to be used, such as the behaviors of the people inside and outside it, everyday items, pieces of urban space glimpsed through its windows, and the interstices between it and its neighboring buildings. The *space of representation* and the *space of occupation* (Henri Lefebvre), which are respectively planned anteriorly and observed posteriorly to when an architectural construction is completed, are superimposed on a single drawing. In light of this, we should be able to re-interpret the earlier question as: “What enables the intermixing of the planned and occupied spaces that belong to differing temporal orders?”

Here we will examine this question through comparing and contrasting the genealogies of various drawing methods and architectural representations from throughout history and the world.

The drawings in *GRAPHIC ANATOMY ATELIER BOW-WOW* fit into the genealogy of so-called “section perspectives”. If we trace the genealogy of these drawings, we will first arrive at the series of works by Paul Rudolph (1918-1997). His section perspective drawing of the Yale Art and Architecture Building (1963) is particularly brilliant. Through it, we can grasp all at once the three-dimensional interrelationships of the spatial components and the bold structural format that supports them. While details such as furniture and everyday items are not depicted, small silhouette figures indicate the enormousness of the interior space through contrast. The same drawing technique was employed regularly at the time by architects in Japan, too. This occurred in conjunction with a contemporaneous contextual current that brought the giantification of architecture. The very way in which these drawings were drawn had sparked the imagination of viewers into envisioning architecture as growing larger and larger to the extent that it might incorporate the city into itself and reach the point where *Architecture = City*. Conversely, the idea of architecture expanding to the scale of a small city had also been synonymous with the idea of the city shrinking down to the size of a single building.

By comprehensively presenting the complex entirety of a building with a single section cut, a section perspective constructs a space that cannot be experienced in reality inside the mind of an observer. A perspective drawn of an unfinished architectural construction would construct a space that *has not been experienced*, in the sense that it does not yet exist in the world; however, in the case of a section



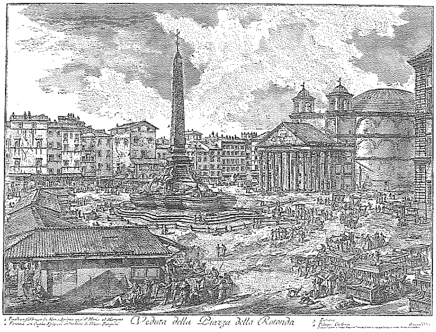
エティエンヌ・ルイ・ブーレー　ニュートン記念堂 *2
Étienne-Louis Boullée, Cenotaph for Isaac Newton

perspective, the space it constructs *cannot be experienced* in the sense that the very viewpoint of the drawing would be unachievable in reality. Something which has not been experienced or cannot be experienced is commonly called a *vision*. A vision provides the driving force behind advancements, as was demonstrated by how Steve Jobs' tireless pursuit of his visions had inspired the engineers and designers who assisted him to create the numerous products of Apple Inc. Rudolph's section perspectives can be seen to have presented visions for *Architecture = City* (Architecture is the City; the City is Architecture). They represent the architect's response to the giantification of architecture that had been taking place within the social and economic context of his time.

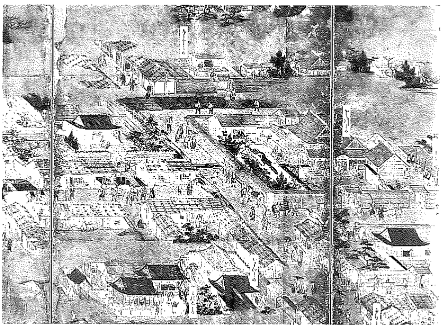
In contrast to how Rudolph's visions have been entrusted to real projects, the series of works drawn by the 18th-century French architect Étienne-Louis Boullée (1728-1799) express visions that stand on their own as projects through their representation.

Boullée lived at a time when the current of Neoclassicism marked by logicality and austerity was starting to spread as a reaction against the Rococo style that had taken root during the reign of King Louis XV. He was not blessed with realized works, but, just as his nickname of the "visionary architect" suggests, he left behind imaginary projects for enormous architectural constructions. The Cenotaph for Isaac Newton was one of such project. Newton was the great celebrity of the 17th century who had put forward his visions to various fields such as physics and astronomy and then proved them. Let us consider his contribution to the subject of gravity, for example: While Johannes Kepler (1571-1630) had already pointed out that gravity existed, his understanding of it had still been on the level of observational experience (e.g. seeing an apple fall from a tree). Newton, however, established the basis for our modern understanding of gravity by recognizing that a gravitational force is present when there are two bodies with mass (an apple and the Earth) exerting attractive forces on one another and the mass of one body (the Earth) is markedly larger than the other. In order to actually observe this, he would have needed to have gone into outer space to look at the whole Earth. This was impossible to do, and anyhow, the apple would have been too small to see. Yet he could still imagine the relationship between them inside his mind. This had given him the liberty to think about the Earth and space without relying on direct experience. Newton subsequently extended his imagination to envision the solar system's structure, which is constituted by the relationships between the orbits of the Sun and planets. Boullée's cenotaph that celebrates Newton's such accomplishments contains a perfect sphere of a size that far surpasses the scale of the human body. His section drawing is drawn along a cut-plane that intersects the space of this sphere at its great circle (a plane that coincides with a diameter of a sphere). Its interior is made to become a planetarium that expresses the starlit sky as light shines through the numerous holes that have been punctured throughout the walls which become thinner closer to the top of the dome. It literally represents a vision of *Architecture = Space*. Perhaps somewhere in his mind, Boullée had been picturing an overlap between Newton and his own architecture while hoping that a revolutionary occurrence of a magnitude as great as the shift in understanding that Newton had brought about would take place in architecture.

Boullée sublimated stylistic Neoclassicism into compositions of geometric forms, and as a result, his architectural visions show a tendency toward a departure from the architectural vocabulary of the past. Contrastingly, Giovanni Battista Piranesi (1720-1778), who had lived in almost exactly the same age as Boullée, is known less for the architecture that he designed himself than for his series of copperplate etchings of ancient Roman ruins, Rome's historical monuments, and his imaginary prisons.



ジョヴァンニ・バッティスタ・ピラネージ　ローマの景観：ロトンダ広場
Giovanni Battista Piranesi, Veduta della Piazza della Rotonda



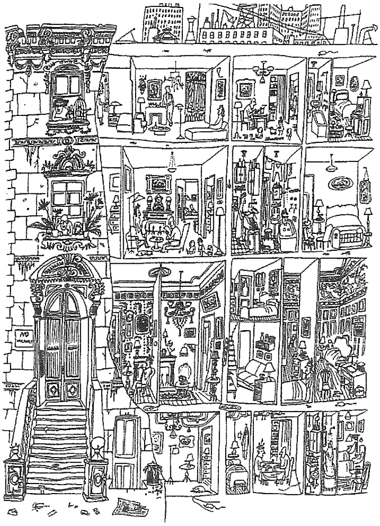
*3

狩野派　洛中洛外図屏風（一部）
Kano School, Rakuchu-Rakugai Folding Screen Paintings (parts)

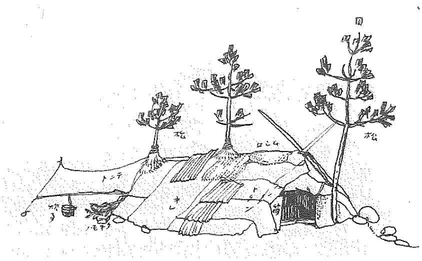
His perspectives of Roman ruins depict not only the dilapidated structures, but also the weeds that have taken root in them, people who mill around among them, and unearthed antique artifacts that have been piled up disorderly in piazzas and along roads. While the subjects of his etchings show a level of accuracy reflective of the regional geographical and archaeological surveys of Rome on which they were modeled, there are many instances where he has represented them in altered positions and exaggerated sizes. Among similar examples of drawings made based on survey measurements of ancient Roman ruins are the reconstruction drawings of the Prix de Rome recipients from the French Academy who had been sent to Rome during the same time period. Compared to how their drawings were made to converge toward the original forms of the depicted subjects by imaginatively filling in the parts that had been lost, Piranesi's copperplate etchings are rich with a sense of invention and playfulness that reflects his interest in cultivating the possibilities hidden in the things that he observed. These copperplate etchings served as landmark illustrations and antique catalogs for the English nobility who visited Rome on the then-popular Grand Tour, and some of the plates are known to have been used to mass-produce as many as 4,000 prints. Seemingly as if to re-create how the real city had formed through history, Piranesi presents elements in his perspectives that had the possibility of existing in the constructed sites that they depict, without distinction between past and present, and he accelerates and augments the latent hypothetical ideas in the urban space to produce fantastical scenes that are not entirely impossible, if albeit more overblown than reality. They reflect analogical visions that position the past and present within the same framework.

In tracing the genealogy of representations like Piranesi's etchings that depict the lives of people in a city as observed together with the architecture around them, there is nothing that we find to be more interesting than the Rakuchu-Rakugai folding screen paintings that were produced by the Kano school of painters during the Sengoku to Edo periods. While these representations do not reflect the disciplinary body of knowledge specific to architects and technical experts, they generally employ the drawing method of the oblique projection (often used in presentations by OMA) that preserves the elevation. Scenes of everyday life and festivities unfolding inside shops and on the streets along thoroughfares lined with the *machiya*-type townhouse buildings of Kyoto are depicted with a sense of synchronized liveliness. The behaviors of the people, which seem to be occurring even beyond the frames of the folding screens, each constitutes a small part of the whole, and the spaces between them are filled with golden clouds. Unlike the perspectives that we have examined previously, neither a center identifiable by a vanishing point (i.e. the position of the observer) nor differences in the sizes of objects caused by depth perception are apparent in these paintings. They do not call out the identity of the observer or assign weight to the depicted subjects. In other words, the unavoidable integration of time and space that occurs within any physical experience, which requires us to be in one place (now) at one time (here), is cancelled. The oblique projection instead generates a sensation that both time and the subjects have been set out side by side en masse. By capitalizing upon this quality, these paintings present paradigmatic visions in which the potential variations of the forms that could be assumed by the subjects and the potential variations of the behaviors that could occur are laid out in parallel with equal weight and in the same moment.

A city is a place where there is an inherent demand for this parallelism of time and space. The book *La Vie mode d'emploi* (*Life: A User's Manual*) (1978) by French novelist Georges Perec (1936-1982) represents a literary elaboration of this vision. He received his inspiration for the novel from Saul Steinberg's drawing



ソール・スタインバーグ　ダブリング・アップ　*4
Saul Steinberg, Doubling Up



今和次郎　震災バラックのスケッチ
Wajiro Kon, Sketch of Post-Earthquake Barracks

神代雄一郎研究室　伊根の集落　*5
Yuichiro Kojiro Research Laboratory, Village of Ine

titled "Doubling Up" (1946) that he saw in *The Art of Living* (1949). Perec attempted to depict a building with its façade removed, just like in the drawing, by establishing a 10×10 grid of rooms and making stories for each room by adhering to combinations of constraints generated from a pre-defined list.

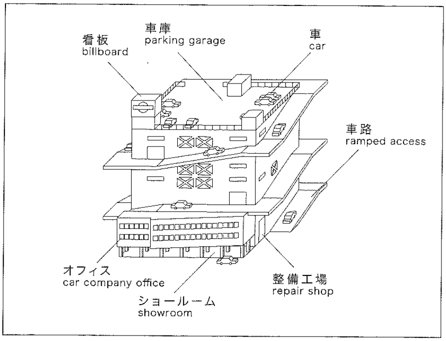
Let us examine Steinberg's drawing closely. The contents of each room are drawn with perspectival depth. Generational differences, differences in family compositions, differences in wealth, and differences in values are all depicted inside the single apartment; for example, it shows the life inside a high-ceilinged room overflowing with luxurious furniture and interior décor on the second floor; the frugal life of an elderly couple living with their cat in a low-ceilinged room on the first floor; the life of a family with children on the third floor; and the lives of bachelors and young couples on the top floor. The drawing can be said to be expressing a sociological vision in the sense that, rather than describing the architecture as existing inside society, it describes the multifariousness of society that has flooded into the architecture.

The visions presented by the Rakuchu-Rakugai folding screen paintings and Steinberg's drawing reflect a common interest in the posterior realm (i.e. space of occupation, as opposed to the anterior realm as discussed at that beginning of this disquisition), and genealogically, they tie into Wajiro Kon's modernology, Tsuneichi Miyamoto's folkloristics, and cultural anthropology. What served to connect this same interest to the genealogy of the study of architecture were the design surveys carried out on traditional villages and traditional architectural constructions. It should be noted that the aforementioned reconstruction surveys of ruins that were conducted by the Prix de Rome recipients, Piranesi's fantastical copperplate etchings, and the Rakuchu-Rakugai folding screen paintings that show a medley of human behaviors all had a design survey aspect to them in the sense that they were based upon observations of already-existing buildings and urban space; however, they were oriented in a different direction. This difference can be attributed to the differences in the contexts or backgrounds against which they were drawn.

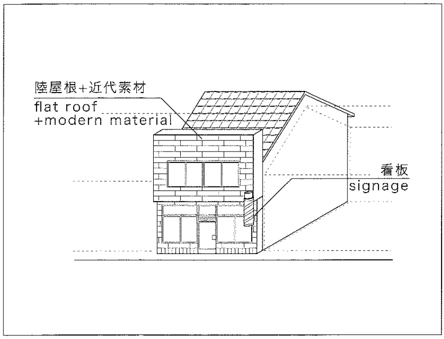
The rise of design surveys particularly in the 1960s was backed by a critical atmosphere that had developed against architecture and the city after modernization. People began to realize that the functionalist architectural constructions and urban spaces that had been promoted and established during modernization were starting to grow beyond humanistic scales (i.e. giantification) and that they lacked a feeling of warmth suitable for living, an organic quality necessary for achieving unity between a place and its regional land and climate, and a sense of complexity in which diverse values can stably coexist.

The dangers had become apparent, for example, of replacing a neighborhood in a city that had been shaped by small closely-knit shops and houses with a large-scale architectural development. This caused the boundaries between the architectural constructions and the streets to harden and to lose their character as permeable thresholds that interpenetrated between both realms, and this in turn deprived people of the room to behave autonomously and threatened to even sever the repetition of their daily routine behaviors. If people cannot repeat their behaviors, their bodies cannot settle into or occupy a place, and the time that they spend practicing their behaviors will not aggregate to form the qualities needed to make a space of comfort. This shows that the aforementioned anterior and posterior conditions are by no means unrelated and that the framework of the anterior planning can prescribe the possibilities for the posterior occupation.

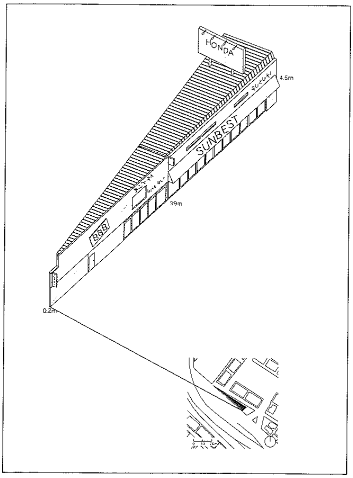
This was what led architects and researchers in the 1960s to go out into the field to conduct observations and inquiries in an attempt to better understand the preeminent appeal of the traditional villages and architectural constructions that had been shaped over the generations. These design surveys were thus



『メイド・イン・トーキョー』 *6
Made in Tokyo



『アトリエ・ワンと歩く 金沢、町家、新陳代謝』 *8
Walking with Atelier Bow-Wow Kanazawa Machiya Metabolism



『ペット・アーキテクチャー・ガイドブック』 *7
Pet Architecture Guide Book

connected to each other at a basic level by the demand of the time to reexamine planning from the aspect of the space of occupation.

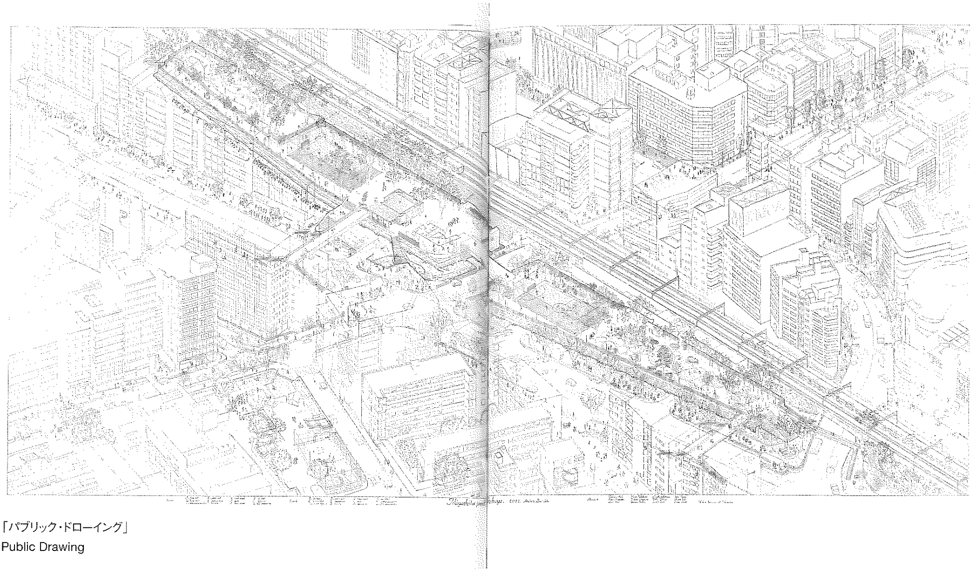
As no plans or unifying designer existed in such villages, the architects and researchers took photographs, made first-hand sketches, collected measurements, and put their knowledge of construction methods to use for parts that they could not see to produce more accurate plan, elevation, section, and section detail drawings. It was common for them to also record the miscellaneous objects that occupied the spaces, such as furniture, stone flooring patterns, animal pens, plantings, and scattered day-to-day items. These assortments of miscellaneous objects contain hidden systems of order, which formed as the objects found stable positions through the making of repeated decisions that were governed by the residents' livelihoods in their villages, their daily lifestyles, annual festivals, and the local climate. This repetition was guided by how the architecture was composed. An ecological vision in which diverse objects and phenomena are interrelated emerged as a result of depicting all of these elements together.

So far, in this discussion, we have clarified the structure through which a vision emerges: representational drawings have a dimension concerned with the subject (what is drawn) and a dimension concerned with the representational technique (how it is drawn); and a vision (the visualization of something that has not been experienced) emerges through the superimposition of these two dimensions. Before we return to the initial question about our illustrations in *GRAPHIC ANATOMY*, let us take a look at some other drawings that we have made at Atelier Bow-Wow and examine them based on this understanding that we have now established.

At Atelier Bow-Wow, we have regularly employed the same oblique projection technique used in the Rakuchu-Rakugai folding screen paintings to make *manga*-like single-line drawings of buildings in the city. This is a method that temporarily suspends aesthetic judgment and cancels any cultural value that may have been assigned to a building, thereby enabling us to observe without bias how the anonymous architectural constructions that make an urban space exist from an ecological point of view. This is what gave rise to *Made in Tokyo* (2001, Kajima Institute Publishing), which is a collection of Tokyo's hybrid "*Da-me* (no-good) architecture"; and *Pet Architecture Guide Book* (2001, World Photo Press), which is a collection of extremely small architectural constructions. In *Kanazawa Machiya Metabolism* (2007, 21st Century Museum of Contemporary Art, Kanazawa), we compared houses in an old city district using oblique projections to preserve their façades, and we positioned the *machiya* townhouses with their 20th-century modifications into the genealogy of the *machiya* that extends back to the Edo period.

Our "public drawings" provide further examples in which we have utilized the qualities of centerlessness and spatiotemporal parallelism offered by the oblique projection to represent public space. We conceived the public drawings as a way of depicting projects that intervene on the public space, such as Miyashita Park, the Kitamoto Station West Square, and the BMW Guggenheim Lab. These drawings describe an ecological area within the urban space that is centered on the projects. In them, we draw the architectural constructions in the surrounding environment, the roads, the open spaces of the projects, and parks with equal weight and density. Moreover, we have taken the idea of multiplicity in the urban space and put it into practice with the drawing method itself by having multiple people simultaneously draw selected subjects of their choice onto a large sheet of paper with pencils.

The paper surface is also a space. The act of drawing on it with a pencil is accompanied by the body.



「パブリック・ドローイング」
Public Drawing

Obviously, it takes a great amount of time to complete. However, through experiencing this process, one will steadily and surely occupy the space of the paper. The sensation of occupying a space posteriorly to the completion of an architectural construction is thus practiced and fixed onto the paper through the act of drawing.

Now, how can we position the *GRAPHIC ANATOMY* illustrations in relation to the architectural representations that we have examined? The illustrations depict the contents of a project that have been planned anteriorly to its completion, such as the forms, arrangements, relationships, and connections of the spaces which are shown through sections and plans, together with internal technical details which are shown through walls and roofs that have been cut away. Additionally, they depict within the depths of their one-point perspective the contents that are observed posteriorly, such as furniture and everyday items that have been brought into the space, views through the windows, and the behaviors of people. We have overlaid these things that are normally drawn separately with different intentions under different circumstances on a single drawing with the aim to generate some kind of connection between the objects and phenomena that are conventionally divided into the categories of the anterior and posterior or the planned and occupied.

If a certain place is occupied, this means that the behaviors of its multifarious elements (not only people, but also light, wind, heat, etc.) are in a state of equilibrium. The behavior of each element is determined by the relationship between the immanent principle within the element and the context that regulates the extent to which it can perform its behavior (the capable range of the behavior). There is no doubt that what the context determines is largely dependent upon the physical composition of the place in question. The behaviors that are produced again and again within this composition are accompanied by a special framework of time that is in repetition. The distinction between the anterior planning and posterior occupation is relativized through the introduction of this framework that reflects a different sense of value to the framework for linearly-progressing time that demarcates the divide between the front/before and back/after in relation to when an architectural construction is completed. The sense of value introduced by the framework of repetitive time calls for us to examine the faculty of architecture that enables it to bring into equilibrium the multifarious behaviors that have been passed on timelessly throughout the ages—such as the behaviors of nature, the behaviors constructed by people in response to nature, and the behaviors that people have internalized through constructing society—and to open up the knowledge it offers to the practice of architecture today.

We seek to shift away from the anterior/posterior separation of the planning and occupation to instead introduce the framework of repetition that is grounded upon the behaviors that are supported by an architectural composition—this is the vision of our illustrations and, for the time being, our response to the initial question.

*1 Paul Rudolph. *Bauten und Projekte.* Hatje Cantz Verlag, 1970.

*2 Emil Kaufmann. *Three Revolutionary Architects: Boullée, Ledoux, and Lequeu.* Trans. Hidekazu Shirai. Chuokoron Bijutsu Shuppan, 1994.

*3 Michihiro Kojima. *Egakareta Sengoku no Kyoto: Rakuchu-rakugai-zu byobu-e wo yomu.* Yoshikawa Kobunkan, 2009.

*4 Saul Steinberg. *The Art of Living.* Harper and Brothers, 1949.

*5 Meiji University Kojiro Lab and Hosei University Miyawaki Lab. *Fukkoku dezain sabei: Kenchiku Bunka-shi sairoku.* Shokokusha, 2012.

*6 Momoyo Kaijima, Junzo Kuroda and Yoshiharu Tsukamoto. *Made in Tokyo.* Kajima Institute Publishing, 2001.

*7 Tokyo Institute of Technology Tsukamoto Architectural Laboratory and Atelier Bow-Wow. *Pet Architecture Guide Book.* World Photo Press, 2001.

*8 Atelier Bow-Wow. *Walking with Atelier Bow-Wow Kanazawa Machiya Metabolism.* 21st Century Museum of Contemporary Art, Kanazawa, 2007.

Architectural Behaviorology

Written by Atelier Bow-Wow
Translated by Steven Chodoriwsky

1. On behaviorology

This book covers the majority of the works of Atelier Bow-Wow to date. The core of our activities has consisted of designing small houses, conducting urban research, and participating in art exhibitions. As these works have been often realized individually and published through various outlets, the relationships between them may appear unclear from an outside perspective. To us, however, this is in no way schizophrenic; rather, projects tend to contaminate, inform, and mutually develop one another. We have never sought to explain our practice in its entirety with overarching meta-theories. Instead, we have posed—and continue to pose—several naive questions:

In spite of Tokyo's complex appearance, why is it a relatively comfortable place to live? In such a mega-city, what is the significance of designing one single, tiny house? As architects who practice here, what can we do from this point on, when a majority of the necessary public urban amenities have been already constructed? ... Why is vernacular architecture so much more charming and seductive than the newest buildings designed by famous architects? Why do buildings, designed by architects, tend to stand out from their surroundings? ... Why is there so often a misalignment of the positions of user and creator in works of architecture? Why do architects desert users and their surroundings? Why does the doubt that architect's wishes overwhelm the user's wishes persist? What will become of urban space when architects are fascinated first and foremost with new forms of architectural expression? Has harmonious urban space disappeared? Can new types of order emerge that can effectively replace this? What determines the happiness of a building? What is the state of public space today, and what might it become in the future? ...

Without knowing exactly how to tackle these questions, we have fortunately had many opportunities to put possible solutions to the test. We have strived to create livable, viable, and enjoyable spaces, all the while addressing several overlapping concerns—architectural expression, architectural dimension, and their complex relationships to capital and generational change. At this point in time, the word "behavior" comes to mind as a recurrent theme in our interests. Behavior could be central to a hypothesis for understanding the correlations between human life, nature, and the built environment. To contrast: the idea of "function" in architecture had developed through the biological understanding of animals' anatomical systems as discovered in a laboratory setting. But in the observation of living things, such methods tend to align more closely with that of the ecological than the functional. It is akin to investigating an animal in its natural habitat, as well as its relationship to other animals within a larger network. This method of study has been taken up not only by biology but also by sociology and anthropology, as they share a common thread in their evaluation of modernity's central axioms. Whereas modernist thought elevated such concepts as self-consciousness and the privilege of the human spirit—often at the neglect of others—an ecological approach to these fields has sought to diminish this imbalance. In fact, most of the questions raised earlier are similarly based on the criticism of such main tenets of modernism. Following this line of thought, the concept of behavior need not apply solely to human beings, and we can discern at least three main classifications relating explicitly to architecture and urban space. Of course, the first is, still, the behavior of human beings. Next, is the behavior of the natural elements, such as light, heat, water and wind. Third, is the behavior of buildings as observed in their larger context or environment. Behaviorology attempts to place architecture and urban space in a position where these three categories are effectively synthesized.

2. The behavior of human beings, natural elements, and buildings

Human Beings

Within what is surely a broad concept, we would like to concentrate on those daily, repetitive acts of humans which are best observed from a slight distance. Such behavior does not tell of the single individual, clearly expressed and distinct from other beings. Nor does it tell of the mass, where aspects of difference are all but erased. It is between these two, at a scale never completely reducible to that of a single unit, where certain customs and habits can be shared.

Natural Elements

Natural elements, such as light, heat, water and wind, deal with the micro-phenomena of physics, which arise outside of and eventually infiltrate buildings. Enclosed air rises when heated; light reflects off surfaces and moves around corners; heat bridges materials; water flows from higher levels to lower levels. They follow basic laws of physics, acting consistently and dependably—at least compared to the relative whimsy of human behavior. Openings, quasi-exterior spaces, and thresholds between inside and outside are logical gathering places for such behaviors. They can be quite mischievous at times: condensation builds along on a windowsill, or wind flits through a crack. Nevertheless, the rules of nature cannot be changed; what we can do, however, is put their inherent properties to best possible use through architecture. Attuned to nature’s stirring, we can obtain a sharper, more enhanced perception of the world.

Buildings

Each building can be viewed as a sentient creature, endowed with its own unique intelligence and a defining set of living characteristics. To deal with a building’s behavior is, in a sense, to go back to the original condition where certain typologies were discovered and, later, perpetuated. The requirements of a building’s typology—its shared formula of articulation and synthesis, developed under specific conditions—are the direct results of the process of repetitive construction. Whether the correspondence of building practices align with a particular climate, with urban planning policy or with local tax regulation, the result is a formula that retains common characteristics—although the effect is far from uniform. Buildings can be seen as identical on the typological level, while still retaining their distinctive elements. A building’s behavior thus cannot be adequately distinguished through its solitary observation, but rather is clarified through the comparison of traits within a larger pool of its peers, siblings, or neighbors.

3. Specific timescales of behavior

The three behaviors outlined above are integrated into daily routine under the premise of repetition, but each carry within them specific timescales and rhythms. For instance, the behavior of natural elements surrounding a building can be adequately observed in a matter of hours, by following, say, the movement of the sun across the sky. In the case of human beings, one day is enough to observe physiological behavior, such as dining and sleeping patterns. For a larger social group such as a company or school, at least one week may be necessary to make sense of its rhythms and routines.

Religious holidays, harvest festival cycles, and other forms of community activity may require an entire year; it may be likewise with seasonal climate change. As such, behaviors change shape depending on the timeframe in question. In terms of a building, it may not be possible to recognize anything clearly regarding its behavior, at least not at the same scale as either humans or natural elements. But within fifty or one hundred years, we can observe how the building's existence has transformed; here, then, its behavior appears. If certain building behaviors are repeated, they may even begin to occupy sizable amounts of territory. And eventually, the proliferation of a characteristic gives rise to urban morphology visible at a much larger scale. Behaviorology attempts to understand this through buildings' typological tendencies, their patterns and influences, and their transformations over time. One clear example of this at work is Tokyo, a city made of houses—and one that has been calamity-free in the over six decades following World War II. As mentioned before, if architecture is favorably positioned to negotiate behaviors of different types, then architectural behaviorology can be seen as the art of synthesizing their disparate rhythms within any single building entity. The vital connection between time and space, eradicated during the twentieth century's orientation to the logic of production, is thus revitalized as a critical pursuit once again.

4. Forms which support behavior

We would like to point out that such a discussion on the behavior of human beings, natural elements and groups of buildings does not objectify the individual building itself. In fact, the building exists only relative to other factors, causing its individuality to disappear altogether. Each is formed according to basic principles of nature, and works to optimize the performance of each factor included therein. In this way, the form of the building is situated to share an ecological relationship with the diverse behaviors of different elements. In order to make architecture intervene in the topic of behavior, form must be reconsidered as a complement to behaviors already in effect. That is to say, the building allows the elements to behave optimally, and consistent with their very nature.

Human beings

We often use the example of furniture and its relationship to the posture of its human users. Take the situation where several people are in a lengthy discussion. The participants, required to concentrate, should be positioned to face one another. This normal setting, where people sit on chairs around a table, is what makes such protracted concentration possible. Here the furniture acts as a jig, positioning the human body for the purpose at hand. After all, a body's orientation consists of both front and back, and the configuration of a chair similarly reflects this fact.

Inside the small houses of Tokyo (where distances between articles of furniture may very well be the shortest in the world), a near-torturous landscape is often produced from the poorly coordinated orientations of various elements. Thus it becomes especially important to integrate, well beyond a building's basic enclosure, a sense of spatial expansiveness that reaches out to the city. Expressing its inherent "open-ness" and "closed-ness" may be achieved through the careful alignment of furniture with openings and walls. In the case of urban public space, the preferable condition is that strangers can behave as they like, while still sharing the same space together. If we are to consider further why this is preferred, it is contingent upon the disposition of elements and human beings that come together to characterize the place.

Natural elements

As long as we are on earth, established laws of physics cannot simply be cancelled or ignored. The intrinsic behaviors of natural elements therefore form a microclimate, influencing each space's quality, whether interior or exterior. For example, a height difference between spaces invites heated air, produced by rhythms of direct sunshine and human activity, to rise from lower to upper parts; without any height difference, no movement occurs. Openings at the top exhaust heated air; low openings provide fresh air from outside. This mechanism of gravity ventilation which utilizes nature's basic features and strengths is not particularly special on its own, but once one really begins to imagine this behavior of air and heat, the form of space can be perceived as ecologically entwined with the flux of natural elements. If we optimize this kind of performance, it is not inconceivable that buildings resemble living, breathing creatures. In this kind of space, science turns into poetics. Architecture becomes the framework in which this can occur.

Buildings

In places where certain attributes of a building repeat and accumulate, a streetscape order is produced. For such an appearance to emerge, these places were not planned, nor were there original blueprints. Rather, their forms seem to have stabilized after many years. Enduring repetition over time, both the unique elements and the overall compositions of built form could only survive through a process of continuous trial and error. Take Venice, for instance. Individual buildings, though far from homogenous, share a certain set of characteristics dealing with their close relationship to water and boats. At the same time, they exhibit unique differences within a particular range, without veering far from their shared vocabulary; divergence in this way demonstrates both a retroactive quality as well as an inherent flexibility. This range, which can be likened to the gravitational pull of an axis—the architectural language—could be called the behavior of buildings. As discussed previously, this is not cultivated within a short period of time, but rather may require generations. Furthermore, manifest in an individual building and operating at different scales are the behaviors of human beings and natural elements. They introduce the existence of micro-flux—the movement of things smaller than the building itself—further defining the quality of architectural space. On the other hand, the behavior of even a single building must necessarily be framed in its larger context, at an urban scale, where accumulations of buildings with individual components can be compared and contrasted. Thus the existence of individual buildings can be treated as a potentially important influence on the quality of collective space. Following this, a form that properly supports a building's behavior overlaps with its existing conditions, and it becomes possible for that building to repeat and accumulate. These conditions, which equally affect any type of building, allow for groups of buildings with shared aspects to be collected. For example, in the absence of certain infrastructure—roadways, water and electricity supply, and so on—buildings have no ability to repeat, accumulate, and thrive. In another case, buildings built on a slope can be grouped insofar as they share the issue of adapting to topographical features. In locales dominated by sunshine, rain, or snow, features appear in the buildings that adapt admirably to the climatic conditions—conditions which transcend social differences and favor no individual site.

5. Interplay between different behaviors

Until now, discussions on the different categories of behavior have been kept as distinct from one another as possible. In reality, however, there is between them constant commingling—a so-called ecosystem of behavior. Within this, architecture becomes the central node, capably synthesizing and facilitating these disparate behaviors. Architecture makes it possible for daily spatial practice to be properly situated in a much broader context. That which is usually considered solely the realm of social relationships is expanded to include nature and the whole of the cosmos, resulting in a liberation of the human imagination. By way of several examples, we would like to discuss the possibility of an architectural behaviorology that calls attention especially to the interdependence of behaviors at different scales—with architecture as its site and medium.

In winter, human beings are drawn to warm places where sunlight reaches; likewise in summertime, we seek out cool places in the shade. The same could be said about certain activities favoring either light-filled or darkened spaces. It is within these spatial settings that natural, enduring human tendencies exist—enabled by a building's configuration of walls, roofs and openings, which in turn invite the natural elements inside.

Rainwater on a roof flows from down from higher points, following gravity. A roof's pitch follows a straightforward and predetermined natural rule. But why is this? When waterproofing techniques were limited, a single roof's successful reaction to the problem invited repetition, eventually creating a particular roof type throughout the settlement. And even today, in areas where houses share the collective burden of winters with heavy snowfalls, roofs resembling one another create a unity of landscape. The form, refined by its adaptation to the natural elements, is shared by different houses as a common architectural language.

Or, if there is a street, buildings tend to line up and repeat alongside, taking advantage of the fresh air and sunlight it provides. Often, a window's condition of operability defines its size. Along a street, therefore, if there are similar-sized windows, they contain the collective behavior of human beings and other surrounding elements. The windows' repetition can give a certain unity to the entire streetscape, even if their host buildings are different sizes, composed of different materials, or constructed in different eras. Thus, architectural language is a kind of intelligence which creates interplay between divergent behaviors.

Up until now, the discussion touching upon nature has been largely based on physics, but here the conversation considers the more tactile objects of the natural realm. In the case of trees, whether plum or cherry, gingko or maple, the blossoming of their flowers and the changing color of their leaves could be framed in terms of the behavior of nature with a one-year cycle. Through this seasonal change, people are coaxed outside for the event, individually and of their own volition. Then, a food stall or an outdoor market appears, and out of nowhere people have unexpectedly gathered, a spiraling of human activity. Through the arrangements of these installations, an animated public space emerges. This situation, where different behaviors synchronize and overlap, is a uniquely Japanese public space, and ably competes with the vibrancy of the western-style plaza. Once, we encountered such a scene where an old woman, despite being hampered by a leg injury, walked with the support of family members slowly towards the trees of a plum grove, fully in bloom. We imagined that this woman, who might rarely leave home due to its inconvenience, was encouraged by this moment; that the beauty of the plum blossoms gave her courage, while her steps, despite the pain, led her forward. She had come together with others who had also arrived to witness this once-a-year event. Through space and through sentiment, they are all connected indirectly by the plum grove. After the flowers disappear and the people return to their homes, this shared space too is gone; only the trees remain. But during that brief period of time, it is without a doubt that the different rhythms of lives, activities and cycles were synchronized. Behaviors overlap to create a kind of synergy, a subtle intelligence which can be clearly recognized even if there are no buildings. When those embodied rhythms emit a certain suitable frequency—and correspond to a suitable material or location—they can begin to form the shape of buildings and of urban space.

6. Atelier Bow-Wow as seen through behaviorology

The previous examination of behaviorology has aimed to clarify a type of intelligence that is composed of an overlapping of different rhythms. This intelligence's analytical ability and transformability spreads, applying not only to buildings but to all elements of landscape, urban space, and the built environment. Since it is embedded into collective, shared territories, it cannot be monopolized. By working with the question posed at the beginning of the discussion, a direction to proceed becomes apparent, through which more concrete concepts can now be situated. Under each of the following three concepts, we would like to reposition our previous works collected and documented in this book.

Void Metabolism and the Fourth-Generation House

As we are based in Tokyo, we have had the chance to design over twenty houses, many of which call into direct question the meaning of designing a single small house in the context of such a gigantic city. Over time, we began to think that we were assisting in the perpetual regeneration of the grain of the city through this particular kind of house design. In Tokyo, small houses, usually two or three floors high, cover the land surface almost infinitely, with small gardens or greenery inserted in the gaps between them. At a glance, this horizontal "city made of houses" may appear inefficient or stifling. In fact, it is a highly sustainable urban form which regenerates itself quite spontaneously; operating without public tax subsidies, here are privately owned properties, taking advantage of the comprehensive and established railway network. This city, a field of autonomous, self-regenerating grains, can be considered a type of Metabolism, though quite different in form and content from that which was popularized in 1960s architectural thought. At that time, Metabolists symbolized their concepts in terms of the composition of the vertical core—the bundling of lifelines surrounded by detachable capsules. With the benefit of hindsight, we can surmise that the architects of that time believed that the construction of the city would be carried out effectively through a concentration of power and capital. However, the reality of development in those residential areas mentioned above turned out quite differently. The regeneration of houses would revolve not around a core, but a void—the gap space between buildings—and would be propelled by the initiatives of individual families, rather than the accumulation of central capital. Further distinguished from the "Core Metabolism" of fifty years ago, it is within the framework of "Void Metabolism" that the practice of designing small houses in Tokyo's residential areas is a clearly perceivable housing behavior.

If the urban formula of Void Metabolism begins, say, with Tokyo's first suburban developments in the 1920s, then its oldest constituent parts are already ninety years old. Considering that the typical Japanese house has a twenty-six-year average lifespan, houses in these original areas have, in theory, regenerated twice over. Of course, there are differences in lifespan between individual houses, so today's situation can be said to include a mixture of the first, second, and third generations of building. By embedding a 26-year regeneration frequency within the residential area's timeline, we can begin to observe, according to generations, a variety of building behaviors. This ninety-year time period is especially significant considering the changes that have occurred in Japanese society. Political and economic conditions, building regulations, construction technique, not to mention changes to family structures and values—have all seen great change, and are reflected in the times of their construction. In most parts of Tokyo's urban landscape, this overlay of different time periods is fixed in the behavior of the houses, so that, even in buildings found side by side, there can be glaring generational differences. However, such an arrangement, lacking obvious order, is far from chaotic. In fact the houses we produce now cannot escape the position of being a part of the fourth generation, framed by the realities of Void Metabolism. What, therefore, should a "Fourth-Generation House" be?

To address this question, there must first be a critical reconsideration of the behaviors seen in the second- and third-generation houses built following World War II. It becomes important to confront and overcome the fact that modernization promoted a "pure" house made solely for its family members, that the introduction of prerequisite air conditioning eliminated opportunities to spend time in shaded or sheltered outdoor spaces, and that the inevitable "leftover" gaps produced between adjacent homes were defined neither as urban space nor as living space. Unsurprisingly, a lackluster street presence is found throughout such suburban residential neighborhoods. In light of this, we raise three important conditions for the fourth-generation house: that interior spaces be inviting for those who are not members of the family; that quasi-exterior spaces be introduced in a positive manner, coaxing inhabitants out of their homes; and that the gap spaces between neighboring buildings be redefined. Nevertheless, proposals dealing with issues of this kind are possible because Tokyo has enjoyed a period of sixty years of essentially uninterrupted development. Ironically, it is only now that Tokyo is entering into a state of childhood, encountering its own intelligence.

Micro Public Space

Let's also consider the various artworks, installations and exhibitions in various cities worldwide. When you visit a place for the first time and are unsure how to immediately behave, you might observe your surroundings for a while, and gradually, you begin to form an understanding its rules. Then, tentatively, you enter into its circle; this experience can be quite thrilling, and if you happen to be accepted as "one of them"—despite being a stranger from a strange land—you feel very warm. This is a singular, irreplaceable social experience. To be sure, the act of gathering is a universal social behavior, but the methods may vary from culture to culture. And within the public space itself—the veritable stage of gathering—many distinct characteristics can also be recognized. A certain behavior is thus shared by others participating in that same place, melting social distinctions and psychological barriers. If you want to experience the warmth of a group, or empathize with others you don't know, it is first necessary to share a time, a location, and a certain sophistication of behavior suitable for the occasion. Take, for example, the language of the plaza as it is often implemented in modern urban planning. In the case where bureaucratic concerns take the foreground, such open spaces may lack the content to nurture a diverse range of behaviors and, without activity or pressure of any kind, this plaza cannot become anything more than a formal symbol. On the contrary, though they may be inferior in terms of size, facilities or formal design, lively public spaces can be encountered in old city centers, where the local inhabitants' intricate patterns of behavior endure. In other words, if it is truly public, it must thrive out of necessity on the behavior of its users, lest it become an unused, vacant space in the city.

Through our participation in international art festivals around the world, we have used this framework to observe many places which encourage the gathering of people in public space. We have witnessed different relationships between local customs and their supporting physical environment, and studied their orientations, distances, sizes and arrangements. Then, from this research, we have utilized rhetorical devices such as deformation, shifting and replacement to produce new but familiar behaviors. With this ongoing series of projects, we continue to explore the larger concept of Micro Public Space to imagine the various spirals, eddies and flows where people converge and disperse. They appear in various forms—artificial topography, small buildings, mobile structures, large furniture—but they all share the characteristic of a defamiliarized social space, embedded in the fabric of existing buildings and furniture. Daily life is thus reframed, as if by a film or theater director, into something light-hearted, sweet, or humorously self-evident.

Environmental Unit, Generational Typology and Flux Management

Alongside the aforementioned activities, Atelier Bow-Wow have worked on a number of urban research projects, both in Japan (Tokyo, Tsukuba, Mito, and Kanazawa) as well as abroad (Paris, Bangkok, and Chongqing, among others), from whose contents and methodologies several concepts have emerged. First, the concept of the "Environmental Unit" has been employed to make sense of urban spatial practices through the observation of hybrid buildings (*Made in Tokyo*) or tiny buildings (*Pet Architecture*). This concept tries to discover the independent orders originating from the urban environment, which are anchored by single elemental units or buildings. Next, "Generational Typology" has been discussed, in particular regarding our investigation of the transformation of *machiya* (townhouse) types found in Kanazawa. This research investigated the transformation of individual machiyas under the various pressures of modernization, from its original formula established in the Edo period until present-day. Through these transformations, the behavior of machiya was clarified in terms of several distinct, generational typologies. Finally, "Flux Management" explores the behavior of large-scale elements flowing throughout the city—such as water, fire, heat, automobile traffic, and garbage—and how they intervene in the city's administration. During the twentieth century, the population explosion in Tokyo produced many types of potential flux in the urban environment, in turn producing potential damage to the quality of daily life. Recognition of this flux has given rise to various, large-scale socio-infrastructural projects—dams, water detention reservoirs, traffic superstructures, and so on. These are real, fully functioning spaces, whose flux content is nevertheless beholden to following the principles of nature of each flux, albeit at a scale which extends far beyond any single building. If we trace backwards this process of constructing these huge structures in the city, it's possible to make suitable proposals that can reunify urban spaces, in keeping with their organic order.

7. Possibilities for behaviorology

We would like to conclude by revealing the continuing possibilities of behaviorology in relation to the questions raised at the beginning of the discussion. As stated previously, behaviorology can be applied not only to the human beings, but also to natural elements and to buildings. It is a means to organically integrate the built environment across disparate scales: from furniture to architecture, to structures of civil engineering, to the landscape and urban planning. It positions projects within an ecosystem of behaviors as elements which participate in spatial production, forming a larger ecological critique on the separation of the academic, professional and industrial spheres.

It is necessary to introduce the idea of timescale in the observation of behavior. This reveals the uniqueness of the rhythms embedded in the various objects that surround our daily life. The coordination of these different rhythms can result in various encounters: the past with the future, and the social with the natural, building up a spatial and temporal framework for positioning ourselves in the here and now. Such an overlay resembles the temporal arts, such as theater and music, and relativizes compositional concepts from the twentieth century, influenced largely by the visual arts of painting and sculpture.

Behaviors gradually increase in precision and sophistication through repetitive responses to certain conditions. This intelligence, growing through a learning process embedded in a feedback loop, cannot be acquired by any single individual but rather links people living together in an area with the buildings they make, encompassed in the larger social and cultural sphere. In this way architecture stores the intellectual capacity of human beings throughout history. Through the frame of behaviorology, the existence of architecture might be rediscovered for its generosity, as it stands alongside human beings and is mindful of our individual differences.

Behaviorology brings about an immediate shift in subjectivity, inviting many different elements together and calling into question who or what may be the main protagonist of a space. Through this ecological approach, our imagination follows the principles of nature and experiences space from a variety of perspectives. When one is surrounded by and synchronized to the livable rhythms embedded in different behaviors—there is no experience quite so delightful.

SCIENCE IN ACTION

How to follow scientists and engineers through society

Bruno Latour

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INTRODUCTION

Opening Pandora's Black Box

Scene 1: On a cold and sunny morning in October 1985, John Whittaker entered his office in the molecular biology building of the Institut Pasteur in Paris and switched on his *Eclipse MV/8000* computer. A few seconds after loading the special programs he had written, a three-dimensional picture of the DNA double helix flashed onto the screen. John, a visiting computer scientist, had been invited by the Institute to write programs that could produce three-dimensional images of the coils of DNA and relate them to the thousands of new nucleic acid sequences pouring out every year into the journals and data banks. 'Nice picture, eh?' said his boss, Pierre, who was just entering the office. 'Yes, good machine too,' answered John.

Scene 2: In 1951 in the Cavendish laboratory at Cambridge, England, the X-ray pictures of crystallised deoxyribonucleic acid were not 'nice pictures' on a computer screen. The two young researchers, Jim Watson and Francis Crick[1], had a hard time obtaining them from Maurice Wilkins and Rosalind Franklin in London. It was impossible yet to decide if the form of the acid was a triple or a double helix, if the phosphate bonds were at the inside or at the outside of the molecule, or indeed if it was an helix at all. It did not matter much to their boss, Sir Francis Bragg, since the two were not supposed to be working on DNA anyway, but it mattered a lot to them, especially since Linus Pauling, the famous chemist, was said to be about to uncover the structure of DNA in a few months.

Scene 3: In 1980 in a Data General building on Route 495 in Westborough, Massachusetts, Tom West[2] and his team were still trying to debug a makeshift prototype of a new machine nicknamed *Eagle* that the company had not planned to build at first, but that was beginning to rouse the marketing department's interest. However, the debugging program was a year behind schedule. Besides, the choice West had made of using the new PAL chips kept delaying the machine – renamed *Eclipse MV/8000*, since no one was sure at the time if the company manufacturing the chips could deliver them on demand. In the meantime, their main competitor, DEC, was selling many copies of its *VAX 11/780*, increasing the gap between the two companies.

(1) Looking for a way in

Where can we start a study of science and technology? The choice of a way in crucially depends on good timing. In 1985, in Paris, John Whittaker obtains 'nice pictures' of DNA on a 'good machine'. In 1951 in Cambridge Watson and Crick are struggling to define a shape for DNA that is compatible with the pictures they glimpsed in Wilkins's office. In 1980, in the basement of a building, another team of researchers is fighting to make a new computer work and to catch up with DEC. What is the meaning of these 'flashbacks', to use the cinema term? They carry us back through space and time.

When we use this travel machine, DNA ceases to have a shape so well established that computer programs can be written to display it on a screen. As to the computers, they don't exist at all. Hundreds of nucleic acid sequences are not pouring in every year. Not a single one is known and even the notion of a sequence is doubtful since it is still unsure, for many people at the time, whether DNA plays any significant role in passing genetic material from one generation to the next. Twice already, Watson and Crick had proudly announced that they had solved the riddle and both times their model had been reduced to ashes. As to the 'good machine' *Eagle*, the flashback takes us back to a moment when it cannot run any program at all. Instead of a routine piece of equipment John Whittaker can switch on, it is a disorderly array of cables and chips surveyed by two other computers and surrounded by dozens of engineers trying to make it work reliably for more than a few seconds. No one in the team knows yet if this project is not going to turn out to be another complete failure like the *EGO* computer on which they worked for years and which was killed, they say, by the management.

In Whittaker's research project many things are unsettled. He does not know how long he is going to stay, if his fellowship will be renewed, if any program of his own can handle millions of base pairs and compare them in a way that is biologically significant. But there are at least two elements that raise no problems for him: the double helix shape of DNA and his Data General computer. What was for Watson and Crick the problematic focus of a fierce challenge, that won them a Nobel Prize, is now the basic dogma of his program, embedded in thousand of lines of his listing. As for the machine that made West's team work day and night for years, it is now no more problematic than a piece of furniture as it hums quietly away in his office. To be sure, the maintenance man of Data General stops by every week to fix up some minor problems; but neither the man nor John have to overhaul the computer all over again and force the company to develop a new line of products. Whittaker is equally well aware of the many problems plaguing the Basic Dogma of biology – Crick, now an old gentleman, gave a lecture at the Institute on this a few weeks ago – but neither John nor his boss have to rethink entirely the shape of the double helix or to establish a new dogma.

The word **black box** is used by cyberneticians whenever a piece of machinery or a set of commands is too complex. In its place they draw a little box about which they need to know nothing but its input and output. As far as John Whittaker is concerned the double helix and the machine are two black boxes. That is, no matter how controversial their history, how complex their inner workings, how large the commercial or academic networks that hold them in place, only their input and output count. When you switch on the *Eclipse* it runs the programs you load; when you compare nucleic acid sequences you start from the double helix shape.

The flashback from October 1985 in Paris to Autumn 1951 in Cambridge or December 1980 in Westborough, Massachusetts, presents two completely different pictures of each of these two objects, a scientific fact – the double-helix – and a technical artefact – the *Eagle* minicomputer. In the first picture John Whittaker uses two black boxes because they are unproblematic and certain; during the flashback the boxes get reopened and a bright coloured light illuminates them. In the first picture, there is no longer any need to decide where to put the phosphate backbone of the double helix, it is just there at the outside; there is no longer any squabble to decide if the *Eclipse* should be a 32-bit fully compatible machine, as you just hook it up to the other NOVA computers. During the flashbacks, a lot of people are introduced back into the picture, many of them staking their career on the *decisions* they take: Rosalind Franklin decides to reject the model-building approach Jim and Francis have chosen and to concentrate instead on basic X-ray crystallography in order to obtain better photographs; West decides to make a 32-bit compatible machine even though this means building a tinkered 'kludge', as they contemptuously say, and losing some of his best engineers, who want to design a neat new one.

In the Pasteur Institute John Whittaker is taking no big risk in believing the three-dimensional shape of the double helix or in running his program on the *Eclipse*. These are now routine choices. The risks he and his boss take lie elsewhere, in this gigantic program of comparing all the base pairs generated by molecular biologists all over the world. But if we go back to Cambridge, thirty years ago, who should we believe? Rosalind Franklin who says it might be a three-strand helix? Bragg who orders Watson and Crick to give up this hopeless work entirely and get back to serious business? Pauling, the best chemist in the world, who unveils a structure that breaks all the known laws of chemistry? The same uncertainty arises in the Westborough of a few years ago. Should West obey his boss, de Castro, when he is explicitly asked *not* to do a new research project there, since all the company research has now moved to North Carolina? How long should West pretend he is not working on a new computer? Should he believe the marketing experts when they say that all their customers want a fully compatible machine (on which they can reuse their old software) instead of doing as his competitor DEC does a 'culturally compatible' one (on which they cannot reuse their software but only the most basic commands)? What confidence should he have in his old team burned out by the failure of the *EGO* project? Should he risk using the new PAL chips instead of the older but safer ones?

Figure I.1

Uncertainty, people at work, decisions, competition, controversies are what one gets when making a flashback from certain, cold, unproblematic black boxes to their recent past. If you take two pictures, one of the black boxes and the other of the open controversies, they are utterly different. They are as different as the two sides, one lively, the other severe, of a two-faced Janus. 'Science in the making' on the right side, 'all made science' or 'ready made science' on the other; such is Janus *bifrons*, the first character that greets us at the beginning of our journey.

In John's office, the two black boxes cannot and should not be reopened. As to the two controverial pieces of work going on in the Cavendish and in Westborough, they are laid open for us by the scientists at work. The impossible task of opening the black box is made feasible (if not easy) by moving in time and space until one finds the controversial topic on which scientists and engineers are busy at work. This is the first decision we have to make: our entry into science and technology will be through the back door of science in the making, not through the more grandiose entrance of ready made science.

Now that the way in has been decided upon, with what sort of prior knowledge should one be equipped before entering science and technology? In John Whittaker's office the double helix model and the computer are clearly distinct from the rest of his worries. They do not interfere with his psychological mood, the financial problems of the Institute, the big grants for which his boss has applied, or with the political struggle they are all engaged in to create in France a big data bank for molecular biologists. They are just sitting there in the background, their scientific or technical contents neatly distinct from the mess that John is immersed in. If he wishes to know something about the DNA structure or about the *Eclipse*, John opens *Molecular Biology of the Gene* or the *User's Manual*, books that he can take off the shelf. However, if we go back to Westborough or to Cambridge this clean distinction between a context and a content disappears.

Scene 4: Tom West sneaks into the basement of a building where a friend lets him in at night to look at a *VAX* computer. West starts pulling out the printed circuits boards and analyses his competitor. Even his first analysis merges technical and quick economic calculations with the strategic decisions already taken. After a few hours, he is reassured.

> 'I'd been living in fear of VAX for a year,' West said afterward. (. . .) 'I think I got a high when I looked at it and saw how complex and expensive it was. It made me feel good about some of the decisions we've made'.

Then his evaluation becomes still more complex, including social, stylistic and organisational features:

> Looking into the VAX, West had imagined he saw a diagram of DEC's corporate organization. He felt that VAX was too complicated. He did not like, for instance, the system by which various parts of the machine communicated with each other, for his taste, there was too much protocol involved. He decided that VAX embodied flaws in DEC's corporate organization. The machine expressed that phenomenally successful company's cautious, bureaucratic style. Was this true? West said it did not matter, it was a useful theory. Then he rephrased his opinions. 'With VAX, DEC was trying to minimize the risk', he said, as he swerved around another car. Grinning, he went on: 'We're trying to maximize the win, and make Eagle go as fast as a raped ape.'
>
> (Kidder: 1981, p. 36)

This heterogeneous evaluation of his competitor is not a marginal moment in the story; it is the crucial episode when West decides that in spite of a two-year delay, the opposition of the North Carolina group, the failure of the *EGO* project, they can still make the *Eagle* work. 'Organisation', 'taste', 'protocol', 'bureaucracy', 'minimisation of risks', are not common technical words to describe a chip. This is true, however, only once the chip is a black box sold to consumers. When it is submitted to a competitor's trial, like the one West does, all these bizarre words become part and parcel of the technical evaluation. Context and contents merge.

Scene 5: Jim Watson and Francis Crick get a copy of the paper unveiling the structure of DNA written by Linus Pauling and brought to them by his son:

> Peter's face betrayed something important as he entered the door, and my stomach sank in apprehension at learning that all was lost. Seeing that neither Francis nor I could bear any further suspense, he quickly told us that the model was a three-chain helix with the sugar phosphate backbone in the center. This sounded so suspiciously like our aborted effort of last year that immediately I wondered whether we might already have had the credit and glory of a great discovery if Bragg had not held us back.
>
> (Watson: 1968, p. 102)

Was it Bragg who made them miss a major discovery, or was it Linus who missed a good opportunity for keeping his mouth shut? Francis and Jim hurriedly try out the paper and look to see if the sugar phosphate backbone is solid enough to hold the structure together. To their amazement, the three chains described by Pauling had no hydrogen atoms to tie the three strands together. Without them, if they knew their chemistry, the structure will immediately fly apart.

> Yet somehow Linus, unquestionably the world's most astute chemist, had come to the opposite conclusion. When Francis was amazed equally by Pauling's unorthodox chemistry, I began to breathe slower. By then I knew we were still in the game. Neither of us, however, had the slightest clue to the steps that had led Linus to his blunder. If a student had made a similar mistake, he would be thought unfit to benefit from Cal Tech's chemistry faculty. Thus, we could not but initially worry whether Linus's model followed from a revolutionary reevaluation of the acid-based properties of very large molecules. The tone of the manuscript, however, argued against any such advance in chemical theory.
>
> (idem: p. 103)

To decide whether they are still in the game Watson and Crick have to evaluate simultaneously Linus Pauling's reputation, common chemistry, the tone of the paper, the level of Cal Tech's students; they have to decide if a revolution is under way, in which case they have been beaten off, or if an enormous blunder has been committed, in which case they have to rush still faster because Pauling will not be long in picking it up:

> When his mistake became known, Linus would not stop until he had captured the right structure. Now our immediate hope was that his chemical colleagues would be more than ever awed by his intellect and not probe the details of his model. But since the manuscript had already been dispatched to the *Proceedings of the National Academy*, by mid-March at the latest Linus's paper would be spread around the world. Then it would be only a matter of days before the error would be discovered. We had anywhere up to six weeks before Linus again was in full-time pursuit of DNA.
>
> (idem: p. 104)

'Suspense', 'game', 'tone', 'delay of publication', 'awe', 'six weeks delay' are not common words for describing a molecule structure. This is the case at least once the structure is known and learned by every student. However, as long as the structure is submitted to a competitor's probing, these queer words are part and parcel of the very chemical structure under investigation. Here again context and content fuse together.

The equipment necessary to travel through science and technology is at once light and multiple. Multiple because it means mixing hydrogen bonds with deadlines, the probing of one another's authority with money, debugging and bureaucratic style; but the equipment is also light because it means simply leaving aside all the prejudices about what distinguishes the context in which knowledge is embedded and this knowledge itself. At the entrance of Dante's Inferno is written:

ABANDON HOPE ALL YE WHO ENTER HERE.

At the onset of this voyage should be written:

ABANDON KNOWLEDGE ABOUT KNOWLEDGE
ALL YE WHO ENTER HERE.

Learning to use the double helix and *Eagle* in 1985 to write programs reveals none of the bizarre mixture they are composed of; studying these in 1952 or in 1980 reveals it all. On the two black boxes sitting in Whittaker's office it is inscribed, as on Pandora's box: DANGER: DO NOT OPEN. From the two tasks at hand in the Cavendish and in Data General Headquarters, passions, deadlines, decisions escape in all directions from a box that lies open. Pandora, the mythical android sent by Zeus to Prometheus, is the second character after Janus to greet us at the beginning of our trip. (We might need more than one blessing from more than one of the antique gods if we want to reach our destination safely.)

(2) When enough is never enough

Science has two faces: one that knows, the other that does not know yet. We will choose the more ignorant. Insiders, and outsiders as well, have lots of ideas about the ingredients necessary for science in the making. We will have as few ideas as possible on what constitutes science. But how are we going to account for the closing of the boxes, because they do, after all, close up? The shape of the double helix is settled in John's office in 1985; so is that of the *Eclipse MV/8000* computer. How did they move from the Cavendish in 1952 or from Westborough, Massachusetts, to Paris 1985? It is all very well to choose controversies as a way in, but we need to follow also the closure of these controversies. Here we have to get used to a strange acoustic phenomenon. The two faces of Janus talk at once and they say entirely different things that we should not confuse.

Janus' first dictum:

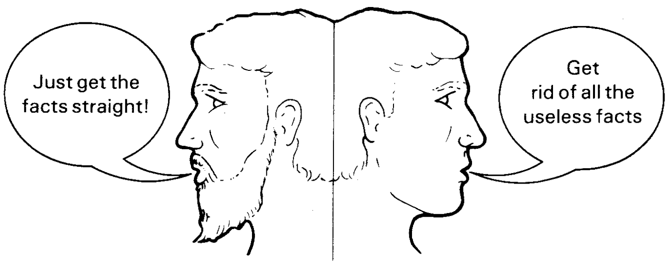


Figure I.2

Scene 6: Jim copies from various textbooks the forms of the base pairs that make up DNA, and plays with them trying to see if a symmetry can be seen when pairing them. To his amazement adenine coupled with adenine, cytosine with cytosine, guanine with guanine and thymine with thymine make very nice superimposable forms. To be sure this symmetry renders the sugar phosphate backbone strangely misshapen but this is not enough to stop Jim's pulse racing or to stop him writing a triumphant letter to his boss.

> I no sooner got to the office and began explaining my scheme than the American crystallographer Jerry Donohue protested that the idea would not work. The tautomeric forms I had copied out of Davidson's book were, in Jerry's opinion, incorrectly assigned. My immediate retort that several other texts also pictured guanine and thymine in the enol form cut no ice with Jerry. Happily he let out that for years organic chemists had been arbitrarily favoring particular tautomeric forms over their alternatives on only the flimsiest of grounds. (. . .) Though my immediate reaction was to hope that Jerry was blowing hot air, I did not dismiss his criticism. Next to Linus himself, Jerry knew more about hydrogen bonds than anyone in the world. Since for many years he had worked at Cal Tech on the crystal structures of small organic molecules, I couldn't kid myself that he did not grasp our problem. During the six months that he occupied a desk in our office, I had never heard him shooting off his mouth on subjects about which he knew nothing. Thoroughly worried, I went back to my desk hoping that some gimmick might emerge to salvage the like-with-like idea.
>
> (Watson: 1968, pp. 121–2)

Jim had got the facts straight out of textbooks which, unanimously, provided him with a nice black box: the enol form. In this case, however, this is the very fact that should be dismissed or put into question. Or at least this is what Donohue says. But whom should Jim believe? The unanimous opinion of organic chemists or *this* chemist's opinion? Jim, who tries to salvage his model, switches from one rule of method, 'get the facts straight', to other more strategic ones, 'look for a weak point', 'choose who to believe'. Donohue studied with Pauling, he worked on small molecules, in six months he never said absurd things. Discipline, affiliation, curriculum vitae, psychological appraisal are mixed together by Jim to reach a decision. Better sacrifice them and the nice like-with-like model, than Donohue's criticism. The fact, no matter how 'straight', has to be dismissed.

> The unforeseen dividend of having Jerry share an office with Francis, Peter, and me, though obvious to all, was not spoken about. If he had not been with us in Cambridge, I might still have been pumping out for a like-with-like structure. Maurice, in a lab devoid of structural chemists, did not have anyone to tell him that all the textbook pictures were wrong. But for Jerry, only Pauling would have been likely to make the right choice and stick by its consequences.
>
> (idem: p. 132)

The advice of Janus' left side is easy to follow when things are settled, but not as long as things remain unsettled. What is on the left side, universal well-known facts of chemistry, becomes, from the right side point of view, scarce pronouncements uttered by two people in the whole world. They have a *quality* that crucially depends on localisation, on chance, on appraising simultaneously the worth of the people and of what they say.

Janus's second dictum:

Figure I.3

Scene 7: West and his main collaborator, Alsing, are discussing how to tackle the debugging program:

> 'I want to build a simulator, Tom.'
> 'It'll take too long, Alsing. The machine'll be debugged before you get your simulator debugged.'
> This time, Alsing insisted. They could not build Eagle in anything like a year if they had to debug all the microcode on prototypes. If they went that way, moreover, they'd need to have at least one and probably two extra prototypes right from the start, and that would mean a doubling of the boring, grueling work of updating boards. Alsing wanted a program that would behave like a perfected Eagle, so that they could debug their microcode separately from the hardware.
> West said: 'Go ahead. But I betchya it'll all be over by the time you get it done.'
>
> (Kidder: 1981, p. 146)

The right side's advice is strictly followed by the two men since they want to build the best possible computer. This however does not prevent a new controversy starting between the two men on how to mimic in advance an efficient machine. If Alsing cannot convince one of his team members, Peck, to finish in six weeks the simulator that should have taken a year and a half, then West will be right: the simulator is not an efficient way to proceed because it will come too late. But if Alsing and Peck succeed, then it is West's definition of efficiency which will turn out to be wrong. Efficiency will be the consequence of who succeeds; it does not help deciding, on the spot, who is right and wrong. The right side's advice is all very well once *Eagle* is sent to manufacturing; before that, it is the left side's confusing strategic advice that should be followed.

Janus' third dictum:

Figure I.4

Scene 8: West has insulated his team for two years from the rest of the company. 'Some of the kids,' he says, 'don't have a notion that there's a company behind all of this. It could be the CIA funding this. It could be a psychological test' (Kidder: 1982, p. 200). During this time, however, West has constantly lobbied the company on behalf of *Eagle*. Acting as a middle-man he has filtered the constraints imposed on the future machine by de Castro (the Big Boss), the marketing department, the other research group in North Carolina, the other machines presented in computer fairs, and so on. He was also the one who kept negotiating the deadlines that were never met. But there comes a point when all the other departments he has lobbied so intensely want to see something, and call his bluff. The situation becomes especially tricky when it is clear at last that the North Carolina group will not deliver a machine, that DEC is selling *VAX* like hot cakes and that all the customers want a supermini 32-bit fully compatible machine from Data General. At this point West has to break the protective shell he has built around his team. To be sure, he designed the machine so as to fit it in with the other departments' interests, but he is still uncertain of their reaction and of that of his team suddenly bereft of the machine.

> As the summer came on, increasing numbers of intruders were being led into the lab – diagnostic programmers and, particularly, those programmers from Software. Some Hardy Boys had grown fond of the prototypes of Eagle, as you might of a pet or a plant you've raised from a seedling. Now Rasala was telling them that they couldn't work on their machines at certain hours, because Software needed to use them. There was an explanation: the project was at a precarious stage; if Software didn't get to know and like the hardware and did not speak enthusiastically about it, the project might be ruined; the Hardy Boys were lucky that Software wanted to use the prototypes – and they had to keep Software happy.
>
> (idem: p. 201)

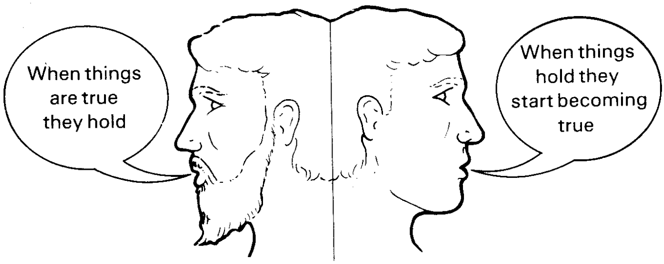
Not only the Software people have to be kept happy, but also the manufacturing people, those from marketing, those who write the technical documentation, the designers who have to place the whole machine in a nice looking box (not a black one this time!), not mentioning the stockholders and the customers. Although the machine has been conceived by West, through many compromises, to keep all these people happy and busy, he cannot be sure it is going to hold them together. Each of the interest groups has to try their own different sort of tests on the machine and see how it withstands them. The worst, for Tom West, is that the company manufacturing the new PAL chips is going bankrupt, that the team is suffering a *post partum* depression, and that the machine is not yet debugged. 'Our credibility, I think, is running out,' West tells his assistants. *Eagle* still does not run more than a few seconds without flashing error messages on the screen. Every time they painstakingly pinpoint the bug, they fix it and then try a new and more difficult debugging program.

> Eagle was failing its Multiprogramming Reliability Test mysteriously. It was blowing away, crashing, going out to never-never land, and falling off the end of the world after every four hours or so of smooth running.
>
> 'Machines somewhere in the agony of the last few bugs are very vulnerable,' says Alsing. 'The shouting starts about it. It'll never work, and so on. Managers and support groups start saying this. Hangers-on say, "Gee, I thought you'd get it done a lot sooner." That's when people start talking about redesigning the whole thing.'
>
> Alsing added, 'Watch out for Tom now.'
>
> West sat in his office. 'I'm thinking of throwing the kids out of the lab and going in there with Rasala and fix it. It's true. I don't understand all the details of that sucker, but I will, and I'll get it to work.'
>
> 'Gimme a few more days,' said Rasala.
>
> (idem: p. 231)

A few weeks later, after *Eagle* has successfully run a computer game called Adventure, the whole team felt they had reached one approximate end: 'It's a computer,' Rasala said (idem: p. 233). On Monday 8 October, a maintenance crew comes to wheel down the hall what was quickly becoming a black box. Why has it become such? Because it is a good machine, says the left side of our Janus friend. But it was not a good machine before it worked. Thus while it is being made it cannot convince anyone *because* of its good working order. It is only after endless little bugs have been taken out, each bug being revealed by a new trial imposed by a new interested group, that the machine will *eventually* and *progressively* be made to work. All the reasons for why it will work once it is finished do not help the engineers while they are making it.

Scene 9: How does the double helix story end? In a series of trials imposed on the new model by each of the successive people Jim Watson and Francis Crick have worked with (or against). Jim is playing with cardboard models of the base pairs, now in the keto form suggested by Jerry Donohue. To his amazement he realises that the shape drawn by pairing adenine with thymine and guanine with cytosine are superimposable. The steps of the double helix have the same shape. Contrary to his earlier model, the structure might be complementary instead of being like-with-like. He hesitates a while, because he sees no reason at first for this complementarity. Then he remembers what was called 'Chargaff laws', one of these many empirical facts they had kept in the background. These 'laws' stated that there

Janus's fourth dictum:



was always as much adenine as thymine and as much guanine as cytosine, no matter which DNA one chose to analyse. This isolated fact, devoid of any meaning in his earlier like-with-like model, suddenly brings a new strength to his emerging new model. Not only are the pairs superimposable, but Chargaff laws can be made a consequence of his model. Another feature came to strengthen the model: it suggests a way for a gene to split into two parts and then for each strand to create an exact complementary copy of itself. One helix could give birth to two identical helices. Thus biological meaning could support the model.

Still Jim's cardboard model could be destroyed in spite of these three advantages. Maybe Donohue will burn it to ashes as he did the attempt a few days earlier. So Jim called him to check if he had any objection. 'When he said no, my morale skyrocketed' (Watson: 1968, p. 124). Then it is Francis who rushes into the lab and 'pushes the bases together in a number of ways'. The model, this time, *resists* Francis's scepticism. There are now many decisive elements tied together with and by the new structure.

Still, all the convinced people are in the same office and although they think they are right, they could still be deluding themselves. What will Bragg and all the other crystallographers say? What objections will Maurice Wilkins and Rosalind Franklin, the only ones with X-rays pictures of the DNA, have? Will they see the model as *the* only form able to give, by projection, the shape visible on Rosalind's photographs? They'd like to know fast but dread the danger of the final showdown with people who, several times already, have ruined their efforts. Besides, another ally is missing to set up the trial, a humble ally for sure but necessary all the same: 'That night, however, we could not firmly establish the double helix. Until the metal bases were on hand, any model building would be too sloppy to be convincing' (idem: p. 127). Even with Chargaff laws, with biological significance, with Donohue's approval, with their excitement, with the base pairing all on their side, the helix is still sloppy. Metal is necessary to reinforce the structure long enough to withstand the trials that the competitors/colleagues are going to impose on it.

The remainder of the double helix story looks like the final rounds of a presidential nomination. Every one of the other contenders is introduced into the office where the model is now set up, fights with it for a while before being quickly

> overwhelmed and then pledging complete support to it. Bragg is convinced although still worried that no one more serious than Jim and Francis had checked the helix. Now for the big game, the encounter between the model and those who for years had captured its projected image. 'Maurice needed but a minute's look at the model to like it.' 'He was back in London only two days before he rang up to say that both he and Rosy found that their X-ray data strongly supported the double helix' (p. 131). Soon Pauling rallies himself to the structure, then it is the turn of the referees of *Nature*.

'Of course,' says the left side of Janus, 'everyone is convinced because Jim and Francis stumbled on the right structure. The DNA shape itself is enough to rally everyone.' 'No, says the right side, every time someone else is convinced it progressively becomes a more right structure.' Enough is never enough: years later in India and New Zealand other researchers were working on a so called 'warped zipper'[3] model that did everything the double helix does – plus a bit more; Pauling strongly supported his own structure that had turned out to be entirely wrong; Jim found biological significance in a like-with-like structure that survived only a few hours; Rosalind Franklin had been stubbornly convinced earlier that it was a three-strand helix; Wilkins ignored the keto forms revealed by Jerry Donohue; Chargaff's laws were an insignificant fact they kept in the background for a long time; as to the metal atom toys, they have lent strong support to countless models that turned out to be wrong. All these allies appear strong once the structure is blackboxed. As long as it is not, Jim and Francis are still struggling to recruit them, modifying the DNA structure until everyone is satisfied. When they are through, they will follow the advice of Janus's right side. As long as they are still searching for the right DNA shape, they would be better off following the right side's confusing advices.

We could review all the opinions offered to explain why an open controversy closes, but we will always stumble on a new controversy dealing with how and why it closed. We will have to learn to live with two contradictory voices talking at once, one about science in the making, the other about ready made science. The latter produces sentences like 'just do this . . . just do that . . .'; the former says 'enough it never enough'. The left side considers that facts and machines are well determined enough. The right side considers that facts and machines in the making are always **under-determined.**[4] Some little thing is always missing to close the black box once and for all. Until the last minute *Eagle* can fail if West is not careful enough to keep the Software people interested, to maintain the pressure on the debugging crew, to advertise the machine to the marketing department.

(3) The first rule of method

We will enter facts and machines while they are in the making; we will carry with us no preconceptions of what constitutes knowledge; we will watch the closure of

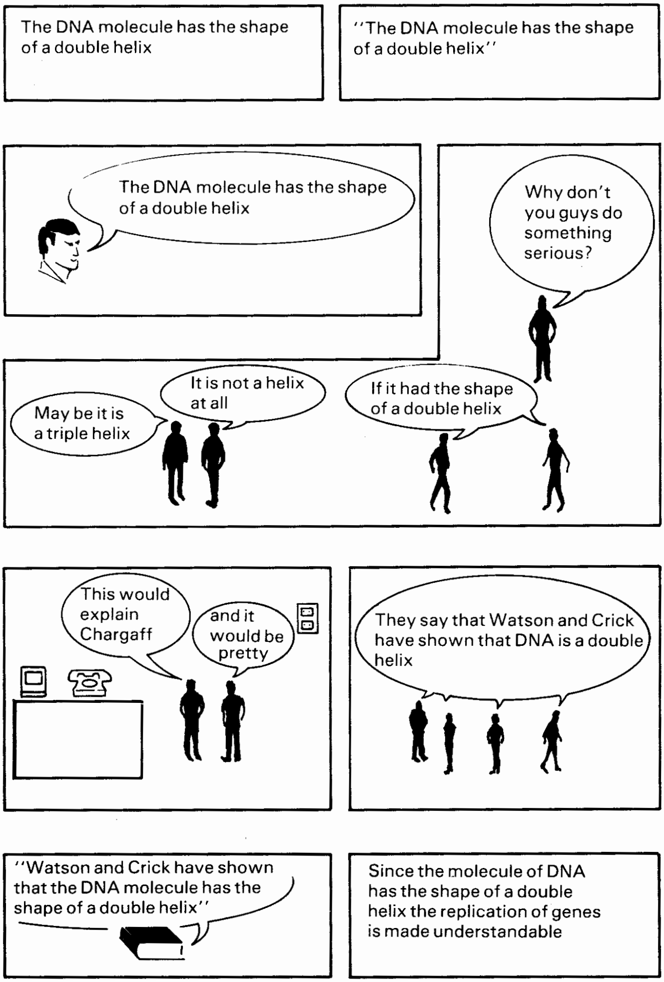

The DNA molecule has the shape of a double helix
"The DNA molecule has the shape of a double helix"
The DNA molecule has the shape of a double helix
Why don't you guys do something serious?
May be it is a triple helix
It is not a helix at all
If it had the shape of a double helix
This would explain Chargaff
and it would be pretty
They say that Watson and Crick have shown that DNA is a double helix
"Watson and Crick have shown that the DNA molecule has the shape of a double helix"
Since the molecule of DNA has the shape of a double helix the replication of genes is made understandable

Figure I.6

the black boxes and be careful to distinguish between two contradictory explanations of this closure, one uttered when it is finished, the other while it is being attempted. This will constitute our **first rule of method** and will make our voyage possible.

To sketch the general shape of this book, it is best to picture the following comic strip: we start with a textbook sentence which is devoid of any trace of fabrication, construction or ownership; we then put it in quotation marks, surround it with a bubble, place it in the mouth of someone who speaks; then we add to this speaking character, another character *to whom* it is speaking; then we place all of them in a specific situation, somewhere in time and space, surrounded by equipment, machines, colleagues; then when the controversy heats up a bit we look at *where* the disputing people go and *what* sort of new elements they fetch, recruit or seduce in order to convince their colleagues; then, we see how the people being convinced stop discussing with one another; situations, localisations, even people start being slowly erased; on the last picture we see a new sentence, without any quotation marks, written in a text book similar to the one we started with in the first picture. This is the general movement of what we will study over and over again in the course of this book, penetrating science from the outside, following controversies and accompanying scientists up to the end, being slowly led out of science in the making.

In spite of the rich, confusing, ambiguous and fascinating picture that is thus revealed, surprisingly few people have penetrated from the outside the inner workings of science and technology, and then got out of it to explain to the outsider how it all works. For sure, many young people have entered science, but they have become scientists and engineers; what they have done is visible in the machines we use, the textbooks we learn, the pills we take, the landscape we look at, the blinking satellites in the night sky above our head. How they did it, we don't know. Some scientists talk about science, its ways and means, but few of them accept the discipline of becoming also an outsider; what they say about their trade is hard to double check in the absence of independent scrutiny. Other people talk about science, its solidity, its foundation, its development or its dangers; unfortunately, almost none of them are interested in science in the making. They shy away from the disorderly mixture revealed by science in action and prefer the orderly pattern of scientific method and rationality. Defending science and reason against pseudo-sciences, against fraud, against irrationality, keeps most of these people too busy to study it. As to the millions, or billions, of outsiders, they know about science and technology through popularisation only. The facts and the artefacts they produce fall on their head like an external fate as foreign, as inhuman, as unpredictable as the olden *Fatum* of the Romans.

Apart from those who make science, who study it, who defend it or who submit to it, there exist, fortunately, a few people either trained as scientists or not, who open the black boxes so that outsiders may have a glimpse at it. They go by many different names (historians of science and technology, economists, sociologists, science teachers, science policy analysts, journalists, philosophers, concerned simply wish to summarise their *method* and to sketch the ground that, sometimes unwittingly, they all have in common. In doing so I wish to help overcome two of the limitations of 'science, technology and society' studies that appear to me to thwart their impact, that is their organisation *by discipline* and *by object*.

Economists of innovation ignore sociologists of technology; cognitive scientists never use social studies of science; ethnoscience is far remote from pedagogy; historians of science pay little attention to literary studies or to rhetoric; sociologists of science often see no relation between their academic work and the *in vivo* experiences performed by concerned scientists or citizens; journalists rarely quote scholarly work on social studies of science; and so on.

This Babel of disciplines would not matter much if it was not worsened by another division made according to the objects each of them study. There exist historians of eighteenth-century chemistry or of German turn-of-the-century physics; even citizens' associations are specialised, some in fighting atomic energy, others in struggling against drug companies, still others against new maths teaching; some cognitive scientists study young children in experimental settings while others are interested in adult daily reasoning; even among sociologists of science, some focus on micro-studies of science while others tackle large-scale engineering projects; historians of technology are often aligned along the technical specialities of the engineers, some studying aircraft industries while others prefer telecommunications or the development of steam engines; as to the anthropologists studying 'savage' reasoning, very few get to deal with modern knowledge. This scattering of disciplines and objects would not be a problem if it was the hallmark of a necessary and fecund *specialisation*, growing from a core of common problems and methods. This is however far from the case. The sciences and the technologies to be studied are the main factors in determining this haphazard growth of interests and methods. I have never met two people who could agree on what the domain called 'science, technology and society' meant – in fact, I have rarely seen anyone agree on the name or indeed that the domain exists!

I claim that the domain exists, that there is a core of common problems and methods, that it is important and that all the disciplines and objects of 'science, technology and society' studies can be employed as so much specialised material with which to study it. To define what is at stake in this domain, the only thing we need is a few sets of concepts sturdy enough to stand the trip through all these many disciplines, periods and objects.

I am well aware that there exist many more sophisticated, subtle, fast or powerful notions than the ones I have chosen. Are they not going to break down? Are they going to last the distance? Will they be able to tie together enough scientists and citizens, cognitive anthropologists or cognitive psychologists), and are most often filed under the general label of 'science, technology and society'. It is on their work that this book is built. A summary of their many *results* and achievements would be worth doing, but is beyond the scope of my knowledge. I empirical facts? Are they handy enough for doing practical exercises*? These are the questions that guided me in selecting from the literature **rules of method** and **principles** and to dedicate one chapter to each pair**. The status of these rules and that of the principles is rather distinct and I do not expect them to be evaluated in the same way. By 'rules of methods' I mean what a priori decisions should be made in order to consider all of the empirical facts provided by the specialised disciplines as being part of the domain of 'science, technology and society'. By 'principles' I mean what is *my* personal summary of the empirical facts at hand after a decade of work in this area. Thus, I expect these principles to be debated, falsified, replaced by other summaries. On the other hand, the rules of method are a package that do not seem to be easily negotiable without losing sight of the common ground I want to sketch. With them it is more a question of all or nothing, and I think they should be judged only on this ground: do they link more elements than others? Do they allow outsiders to follow science and technology further, longer and more independently? This will be the only rule of the game, that is, the only 'meta' rule that we will need to get on with our work.

* The present book was originally planned with exercises at the end of each chapter. For lack of space, these practical tasks will be the object of a second volume.

** Except for the first rule of method defined above. A summary of these rules and principles is given at the end of the book.

Notes

Introduction

1 I am following here James Watson's account (1968).
2 I am following here Tracy Kidder's book (1981). This book, like Watson's, is compulsory reading for all of those interested in science in the making.
3 On this episode see T.D. Stokes (1982).
4 This notion of under-determination is also called the Duhem-Quine principle. It asserts that no one single factor is enough to explain the closure of a controversy or the certainty acquired by scientists. This principle forms the philosophical basis of most social history of sociology of science.

Chapter 1

1 This debate about the MX weapon system has been the object of a long public controversy in the USA.
2 This example is taken from Nicholas Wade (1981). The rest of the controversy is inspired from the book, although it is in part fictional.
3 This example is taken from Michel Callon (1981).
4 Cited in S. Drake (1970, p. 71).
5 I am using here the following article: A. V. Schally, V. Baba, R. M. G. Nair, C. D. Bennett (1971), 'The amino-acid sequence of a peptide with growth hormone-releasing isolated from porcine hypothalamus', *Journal of Biological Chemistry,* vol. 216, no. 21, pp. 6647–50.
6 The field of citation studies has become an independent sub-discipline. For a review see E. Garfield (1979) or the review *Scientometrics* for more recent and more specialised examples. For the context of citation, see M. H. MacRoberts and B. R. MacRoberts (1986).
7 This expression has become traditional since the work of Thomas Kuhn (1962).
8 The Science Citation Index is produced by the Institute for Scientific Information in Philadelphia and has become the basis of much work in science policy.
9 I am using here the following article: R. Guillemin, P. Brazeau, P. Böhlen, F. Esch, N. Ling, W. B. Wehrenberg (1982), 'Growth-hormone releasing

factor from a human pancreatic tumor that caused acromegaly', *Science*, vol. 218, pp. 585–7.
10 The article commented on here is by C. Packer, 'Reciprocal altruism in papio P.', *Nature* 1977 Vol. 265, no. 5593, pp. 441–443. Although this transformation of the literature is a sure telltale of the differences between harder and softer fields, I know of no systematic study of this aspect. For a different approach and on the articles in physics see C. Bazerman (1984).
11 See M. Spector, S. O'Neal, E. Racker (1980), 'Regulation of phosporylation of the ß-subunit of the Ehrlich Ascites tumor Na→K→-ATPase by a protein kinase cascade'. *Journal of Biological Chemistry*, vol. 256, no. 9 pp. 4219–27. On this and many other borderline cases, see W. Broad and N. Wade (1982).
12 For a general presentation see M. Callon, J. Law and A. Rip (eds) (1986).
13 On the somatostatin episode see Wade (1981, chapter 13).
14 For a good introduction or rhetoric in settings other than the scientific ones see C. Perelman (1982).

Chapter 2

1 For an introduction to bibliometry and to the study of citations see E. Garfield (1979); for the co-words analysis see M. Callon, J. Law and A. Rip (eds) (1986); for an introduction to semiotics see F. Bastide (1985).
2 I am following here the work of Trevor Pinch (1986).
3 I am following here the work of Mary Jo Nye (1980, 1986).
4 On this see N. Wade (1981, Chapter 13).
5 I am following here the empirical example studied by H. Collins (1985), although his description of the ways of settling controversies is rather different and will be analysed in Part II of this book.
6 I am following here the work of Farley and Geison, (1974).
7 Later on, however, the controversy was resumed; see R. Dubos (1951). There are always only practical and temporary ends to controversies, as will be shown in the last section.
8 On this controversy see M. Mead (1928) and D. Freeman (1983).
9 I am using here D. MacKenzie's (1978) article. See also his (1981) book on the larger setting of the same controversy.
10 On this episode of the discovery of somatostatin see N. Wade (1981 chapter 13).
11 This excerpt is taken from E. Duclaux's *Traité de biochimie* (1896), vol. II, p. 8. Duclaux was collaborator of Pasteur.
12 I am using here the following article by Pierre and Marie Curie: (1898) 'Sur une substance nouvelle radio-active, contenue dans la pechblende', *Comptes Rendus de l'Académie des Sciences*, vol. 127, pp. 175–8.
13 For the definition of these words and of all the concepts of semiotics see A. Greimas and J. Courtès (1979/1983). For a presentation of semiotics in English see F. Bastide (1985).
14 See J. W. Dauben (1974).
15 For the ultracentrifuge see the nice study by Boelic Elzen (forthcoming).
16 I am alluding here to the remarkable work by A. Desmond (1975).
17 This basic question of relativism has been nicely summed up in many articles by Harry Collins. See in particular his latest book (1985).

CHAPTER 6

Centres of Calculation

Prologue
The domestication of the savage mind

At dawn, 17 July 1787, Lapérouse, captain of *L'Astrolabe*, landed at an unknown part of the East Pacific, on an area of land that was called 'Segalien' or 'Sakhalin' in the older travel books he had brought with him. Was this land a peninsula or an island? He did not know, that is no one in Versailles at the court of Louis XVI, no one in London, no one in Amsterdam in the headquarters of the West Indies Company, could look at a map of the Pacific Ocean and decide whether the engraved shape of what was called 'Sakhalin' was tied to Asia or was separated by a strait. Some maps showed a peninsula, others showed an island; and a fierce dispute had ensued among European geographers as to how accurate and credible the travels books were and how precise the reconnaissances had been. It is in part because there were so many of these disputes – similar to the profusion we studied in Part I – on so many aspects of the Pacific Ocean, that the king had commissioned Lapérouse, equipped two ships, and ordered him to draw a complete map of the Pacific.[1]

The two ships had been provided, as scientific satellites are today, with all the available scientific instruments and skill; they were given better clocks to keep the time, and thus measure the longitude more accurately; they were given compasses to measure the latitude; astronomers had been enlisted to mend and tend the clocks and to man the instruments; botanists, mineralogists and naturalists were on board to gather specimens; artists had been recruited to sketch and paint pictures of those of the specimens that were too heavy or too fragile to survive the return trip; all the books and travel accounts that had been written on the Pacific had been stocked in the ship's library to see how they compared with what the travellers would see; the two ships had been loaded with goods and bargaining chips in order to evaluate all over the world the relative prices of gold, silver, pelts, fish, stones, swords, anything that could be bought and sold at a profit, thus trying out possible commercial routes for French shipping.

This morning in July, Lapérouse was very surprised and pleased. The few savages – all males – that had stayed on the beach and exchanged salmon for pieces of iron were much less 'savage' than many he had seen in his two years of travel. Not only did they seem to be sure that Sakhalin was an island, but they also appeared to understand the navigators' interest in this question and what it was to draw a map of the land viewed from above. An older Chinese sketched on the sand the country of the 'Mantchéoux', that is, China, and his island; then he indicated with gestures the size of the strait separating the two. The scale of the map was uncertain, though, and the rising tide soon threatened to erase the precious drawing. So, a younger Chinese took up Lapérouse's notebook and pencil and drew another map noting the scale by little marks, each signifying a day of travel by canoe. They were less successful in indicating the scale for the depth of the strait; since the Chinese had little notion of the ship's draught, the navigators could not decide if the islanders were talking of relative or of absolute size. Because of this uncertainty, Lapérouse, after having thanked and rewarded these most helpful informants, decided to leave the next morning and to sight the strait for himself, and, hopefully, to cross it and reach Kamchatka. The fog, adverse winds and bad weather made this sighting impossible. Many months later, when they finally reached Kamchatka, they had not seen the strait, but relied on the Chinese to decide that Sakhalin was indeed an island. De Lesseps, a young officer, was asked by Lapérouse to carry the maps, the notebooks and the astronomical bearings they had gathered for two years back to Versailles. De Lesseps made the trip on foot and on horseback under the protection of the Russians, carrying with him these precious little notebooks; one entry among thousands in the notebooks indicated that the question of the Sakhalin island was settled and what the probable bearing of the strait was.

This is the kind of episode that could have been put to use, at the beginning of Chapter 5, in order to make the Great Divide manifest. At first sight, it seems that the differences between Lapérouse's enterprise and those of the natives is so colossal as to justify a deep distinction in cognitive abilities. In less than three centuries of travels such as this one, the nascent science of geography has gathered more knowledge about the shape of the world than had come in millenia. The *implicit* geography of the natives is made *explicit* by geographers; the *local* knowledge of the savages becomes the *universal* knowledge of the cartographers; the fuzzy, approximate and ungrounded *beliefs* of the locals are turned into a precise, certain and justified *knowledge*. To the partisans of the Great Divide, it seems that going from ethnogeography to geography is like going from childhood to adulthood, from passion to reason, from savagery to civilisation, or from first degree intuitions to second degree reflexion.

However, as soon as we apply the sixth rule of method, the Great Divide disappears and other little differences become visible. As I showed in the last chapter, this rule asks us not to take a position on rationality, but simply to consider the movement of the observer, its angle, direction and scale.

Lapérouse crosses the path of the Chinese fishermen *at right angles*; they have never seen each other before and the huge ships are not here to settle. The Chinese have lived here for as long as one can remember whereas the French fleet remains with them for a day. These families of Chinese, as far as one can tell, will remain around for years, maybe centuries; *L'Astrolabe* and *La Boussole* have to reach Russia before the end of the summer. In spite of this short delay, Lapérouse does not simply cross the path of the Chinese ignoring the people on shore. On the contrary, he learns from them as much as he can, describing their culture, politics and economics – after one day of observation! – sending his naturalists all over the forest to gather specimens, scribble notes, take the bearings of stars and planets. Why are they all in a hurry? If they were interested in the island could they not stay longer? No, because they are not so much interested in this place as they are in bringing this place *back* first to their ship, and second to Versailles.

But they are not only in a hurry, they are also under enormous pressure to gather traces that have to be of a certain quality. Why is it not enough to bring back to France personal diaries, souvenirs and trophies? Why are they all so hard-pressed to take precise notes, to obtain and double-check vocabularies from their informants, to stay awake late at night writing down everything they have heard and seen, labelling their specimens, checking for the thousandth time the running of their astronomical clocks? Why don't they relax, enjoy the sun and the tender flesh of the salmon they catch so easily and cook on the beach? Because the people who sent them away are not so much interested in their coming back as they are in the possibility of sending *other* fleets *later*. If Lapérouse succeeds in his mission, the next ship will know if Sakhalin is a peninsula or an island, how deep the strait is, what the dominant winds are, what the mores, resources and culture of the natives are *before* sighting the land. On 17 July 1787, Lapérouse is *weaker* than his informants; he does not know the shape of the land, does not know where to go; he is at the mercy of his guides. Ten years later, on 5 November 1797 the English ship *Neptune* on landing again at the same bay will be much *stronger* than the natives since they will have on board maps, descriptions, log books, nautical instructions – which to begin with will allow them to know that this is the 'same' bay. For the new navigator entering the bay, the most important features of the land will all be seen for the *second* time – the first time was when reading in London Lapérouse's notebooks and considering the maps engraved from the bearings De Lesseps brought back to Versailles.

What will happen if Lapérouse's mission does not succeed? If De Lesseps is killed and his precious treasure scattered somewhere on the Siberian tundra? Or if some spring in the nautical clocks went wrong, making most of the longitudes unreliable? The expedition is wasted. For many more years a point on the map at the Admiralty will remain controversial. The next ship sent away will be *as weak* as *L'Astrolabe*, sighting the Segalien (or is it Sakhalin?) island (or is it a peninsula?) for the *first* time, looking again for native informants and guides; the divide will remain as it is, quite small since the frail and uncertain crew of the

Neptuna will have to rely on natives as poor and frail as them. On the other hand, if the mission succeeds, what was at first a small divide between the European navigator and the Chinese fishermen will have become larger and deeper since the *Neptuna* crew will have less to learn from the natives. Although there is at the beginning not much difference between the abilities of the French and the Chinese navigators, the difference will grow if Lapérouse is part of a network through which the ethnogeography of the Pacific is accumulated in Europe. An asymmetry will slowly begin to take shape between the 'local' Chinese and the 'moving' geographer. The Chinese will remain savage (to the European) and as strong as the *Neptuna* crew, if Lapérouse's notebooks do not reach Versailles. If they do, the *Neptuna* will be better able to *domesticate* the Chinese since everything of their land, culture, language and resources will be known on board the English ship before anyone says a word. Relative degrees of savagery and domestication are obtained by many little tools that make the wilderness known in advance, predictable.

Nothing reveals more clearly the ways in which the two groups of navigators talk at cross purposes, so to speak, than their interest in the inscription. The accumulation that will generate an asymmetry hinges upon the possibility for some traces of the travel to go back to the place that sent the expedition away. This is why the officers are all so much obsessed by bearings, clocks, diaries, labels, dictionaries, specimens, herbaries. Everything depends on them: *L'Astrolabe* can sink provided the inscriptions survive and reach Versailles. This ship travelling through the Pacific is an instrument according to the definition given in Chapter 2. The Chinese, on the other hand, are not all that interested in maps and inscriptions – not because they are unable to draw them (on the contrary their abilities surprise Lapérouse very much) but simply because the inscriptions are not the *final goal* of their travel. The drawings are no more than *intermediaries* for their exchanges between themselves, intermediaries which are used up in the exchange and are not considered important in themselves. The fishermen are able to generate these inscriptions at will on any surface like sand or even on paper when they meet someone stupid enough to spend only a day in Sakhalin who nevertheless wishes to know everything fast for some other unknown foreigner to come back later and safer. There is no point in adding any cognitive difference between the Chinese navigators and the French ones; the misunderstanding between them is as complete as between the mother and the child in Chapter 5 and for the same reason: what is an intermediary of no relevance has become the beginning and the end of a cycle of capitalisation. The difference in their movement is enough and the different emphasis they put on inscriptions ensues. The map drawn on sand is worthless for the Chinese who do not care that the tide will erase it; it is a treasure for Lapérouse, his main treasure. Twice, in his long travels, the captain was fortunate enough to find a faithful messenger who brought his notes back home. De Lesseps was the first; Captain Phillip, met at Botany Bay in Australia in January 1788, was the second. There was no third time. The two ships disappeared and the only traces that were found, well into the nineteenth century, were not maps and herbariums, but the hilt of a sword and a piece of the stern with a fleur-de-lis on it, that had become the door of a savage's hut. On the third leg of their journey the French navigators had not been able to domesticate the savage lands and peoples; consequently, nothing is known with certainty about this part of their voyage.

Part A
Action at a distance

(1) Cycles of accumulation

Can we say that the Chinese sailors Lapérouse met did not know the shape of their coasts? No, they knew it very well; they had to since they were born there. Can we say that these Chinese did not know the shape of the Atlantic, of the Channel, of the river Seine, of the park of Versailles? Yes, we are allowed to say this, they had no idea of them and probably they could not care less. Can we say that Lapérouse knew this part of Sakhalin before landing there? No, it was his first encounter with it, he had to fumble in darkness, taking soundings along the coast. Are we allowed to say that the crew of the *Neptuna* knew this coast? Yes, we may say this, they could look at Lapérouse's notes, and compare his drawings of the landings with what they saw themselves; less sounding, less fumbling in the dark. Thus, the knowledge that the Chinese fishermen had and that Lapérouse did *not* possess had, in some still mysterious way, been provided to the crew of the English ship. So, thanks to this little vignette, we might be able to define the word knowledge.

The first time we encounter some event, we do not know it; we start knowing something when it is at least the *second* time we encounter it, that is, when it is familiar to us. Someone is said to be knowledgeable when whatever happens is only one instance of other events already mastered, one member of the same family. However, this definition is too general and gives too much of an advantage to the Chinese fishermen. Not only have they seen Sakhalin twice, but hundreds and even thousands of times for the more elderly. So they will always be more knowledgeable than these white, ill-shaven, capricious foreigners who arrive at dawn and leave at dusk. The foreigners will die en route, wrecked by typhoons, betrayed by guides, destroyed by some Spanish or Portuguese ship, killed by yellow fever, or simply eaten up by some greedy cannibals . . . as probably happened to Lapérouse. In other words, the foreigner will always be weaker than any one of the peoples, of the lands, of the climates, of the reefs, he meets around the world, always at their mercy. Those who go away from the lands in which they are born and who cross the paths of other people disappear without trace. In this case, there is not even time for a Great Divide to be drawn; no accusation process takes place, no trial of strength between different sociologics occurs, since the moving element in this game, that is the foreigner, vanishes at the first encounter.

If we define knowledge as familiarity with events, places and people seen many times over, then the foreigner will always be the weakest of all except if, by some extraordinary means, whatever happens to him happens at least twice; if the islands he has never landed at before have already been seen and carefully studied, as was the case with the navigator of the *Neptuna*, then, and only then, the moving foreigner might become stronger than the local people. What could these 'extraordinary means' be? We know from the Prologue that it is not enough for a foreigner to have been preceded by one, or two, or hundreds of others, as long as these predecessors either have vanished without trace, or have come back with obscure tales, or keep for themselves rutters only *they* can read, because, in these three cases, the new sailor has gained nothing from his predecessors' travels; for him, everything will happen the first time. No, he will gain an edge only if the other navigators have found a way to *bring* the lands *back with them* in such a manner that he will *see* Sakhalin island, for the first time, at leisure, in his own home, or in the Admiralty office, while smoking his pipe . . ..

As we see, what is called 'knowledge' cannot be defined without understanding what *gaining* knowledge means. In other words, 'knowledge' is not something that could be described by itself or by opposition to 'ignorance' or to 'belief', but only by considering a whole cycle of accumulation: how to bring things back to a place for someone to see it for the first time so that others might be sent again to bring other things back. How to be familiar with things, people and events, which are *distant.* In Figure 6.1 I have sketched the same movement as in Figure 5.4 but instead of focusing on the accusation that takes place at the intersection, I have focused on the accumulation process.

Expedition number one disappears without trace, so there is no difference in 'knowledge' between the first and the second that fumbles its way in darkness always at the mercy of each of the people whose path is crossed. More fortunate

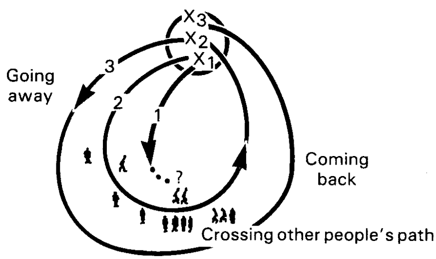


Figure 6.1

than the first, this second expedition not only comes back but brings something (noted X2 in the drawing) that allows the third to be so familiar with the coastline that they can quickly move to other lands bringing home parts of a map of a *new* territory (X3). At every run of this accumulation cycle, more elements are gathered in the centre (represented by a circle at the top); at every run the asymmetry (at the bottom) between the foreigners and the natives grows, ending today in something that indeed looks like a Great Divide, or at least like a disproportionate relation between those equipped with satellites who localise the 'locals' on their computer maps without even leaving their air-conditioned room in Houston, and the helpless natives who do not even see the satellites passing over their heads.

We should not be in a rush to decide what are these 'extraordinary means', what these things noted 'X' in the drawing are, which are brought back by the navigators. We first have to understand under what conditions a navigator can sail overseas and come *back*, that is how a cycle may be drawn at all. To do this, we have to take a much earlier example when these travels abroad were yet more perilous. Three centuries before Lapérouse, in 1484, King John II of Portugal convened a small scientific commission to help navigators finding their way to the Indies.[2]

At this time a first condition has been fulfilled: the heavy and sturdy carracks designed by the Portuguese did not disintegrate any more in storms or long sojourns at sea; the wood of which they were built and the way they were careened made them stronger than waves and tides. In the definition of the term I gave in Chapter 3, they acted as *one element*; they had become a clever machination to control the many forces that tried out their resistance. For instance, all sorts of wind directions, instead of slowing the ships down, were turned into allies by a unique combination of lateen and square rigs. This combination allowed a smaller crew to man a bigger ship, which made crew members less vulnerable to malnutrition and plagues, and captains less vulnerable to mutinies. The bigger size of the carracks made it possible to embark bigger guns which, in turn, rendered more predictable the outcome of all military encounters with the many tiny pirogues of the natives. This size also rendered it practical to bring back a bigger cargo (if there were a return trip).

When the scientific commission convened, the carracks were already very mobile and versatile tools, able to extract compliance from the waves, the winds, the crew, the guns and the natives, but not yet from the reefs and the coastline. These were always more powerful than the carracks since they appeared unexpectedly, wrecking the ships one after the other. How to localise in advance all the rocks instead of being, so to speak, *localised* by them without warning? The solution of the commission was to use the furthest-fetched of all possible helping hands, the sun and the stars, whose slow declination could be turned, with the help of instruments to determine angles, of tables to make the calculation, of training to prepare the pilots, into a not-too-inaccurate approximation of the latitude. After years of compilation, the commission wrote the *Regimento do Astrolabio and do Qadrante.* This book on board every ship gave very practical directions on how to use the quadrant and how to measure the latitude by entering the date, the time, the angle of the sun with the horizon; in addition, the commission compiled all the bearings of good quality that had been made at various latitudes, systematically adding each reliable one. Before this commission, capes, reefs and shoals were stronger than all the ships, but after this, the carracks plus the commission, plus the quadrants, plus the sun, had tipped the balance of forces in favour of the Portuguese carracks: the dangerous coastline could not rear up treacherously and interrupt the movement of the ship.

Still, even with the winds, the wood, the coastline, the crews, the sun, disciplined, aligned, well-drilled and clearly on King John's side, there is no guarantee that a cycle of accumulation will be drawn that will *start* from him and *end* with him, in Lisbon. For instance, Spanish ships may divert the carracks out of their way; or the captains with their ships loaded with precious spices may betray the king and sell them elsewhere to their profit; or Lisbon's investors might keep for themselves most of the profit and baulk at equipping a new fleet to continue the cycle. Thus, in addition to all his efforts in ship designing, cartography and nautical instructions, the king must invent many new ways to extract compliance from investors, captains, custom officers; he must insist on legal contracts to bind, as much as he can, with signatures, witnesses and solemn oaths, his pilots and admirals; he must be adamant on well-kept accounting books, on new schemes to raise money and to share benefits; he must insist on each log book being carefully written, kept out of the enemy's sight, and brought back to his offices in order for its information to be compiled.

Together with the Prologue, this example introduces us to the most difficult stage of this long travel that leads us not through the oceans, but through technoscience. This cumulative character of science is what has always struck scientists and epistemologists most. But in order to grasp this feature, we have to keep in view all the conditions that allow a cycle of accumulation to take place. At this point the difficulties seem enormous because these conditions *cut across* divisions usually made between economic history, history of science, history of technology, politics, administration or law, since the cycle drawn by King John may leak at any seam: it may be that a legal contract is voided by a court, or a shifting political alliance gives Spain the upper hand, or the timber of a ship does not resist a typhoon, or a miscalculation in the *Regiment* sends a fleet ashore, or a mistake in the appraisal of a price renders a purchase worthless, or a microbe brings the plague back with the spices . . . . There is no way to neatly order these links into categories, since they have all been woven together, like the many threads of a macramé, to make up for one another's weaknesses. All the distinctions one could wish to make between domains (economics, politics, science, technology, law) are less important than the unique movement that makes all of these domains conspire towards the same goal: a cycle of accumulation that allows a point to become a *centre* by acting at a distance on many other points.

If we wish to complete our journey we have to define words that help us to follow this heterogeneous mixture and not to be interrupted and baffled every time the cycle-builders change gears going from one domain into another. Will we call 'knowledge' what is accumulated at the centre? Obviously, it would be a bad choice of words because becoming familiar with distant events requires, in the above examples, kings, offices, sailors, timber, lateen rigs, spice trades, a whole bunch of things not usually included in 'knowledge'. Will we call it 'power' then? That would also be a mistake because the reckoning of lands, the filling-in of log books, the tarring of the careen, the rigging of a mast, cannot without absurdity be put under the heading of this word. Maybe we should speak of 'money' or more abstractly of 'profit' since this is what the cycle adds up to. Again, it would be a bad choice because there is no way to call profit the small bundle of figures De Lesseps brings back to Versailles or the rutters put in the hands of King John; nor is the profit the main inducement for Lapérouse, his naturalists, his geographers and his linguists. So how are we to call what is brought back? We could of course talk of 'capital' that is something (money, knowledge, credit, power) that has no other function but to be instantly reinvested into another cycle of accumulation. This would not be a bad word, especially since it comes from *caput*, the head, the master, the centre, the capital of a country, and this is indeed a characterisation of Lisbon, Versailles, of all the places able to join the beginning and the end of such a cycle. However, using this expression would be begging the question: what is capitalised is necessarily turned into capital, it does not tell us what it is – besides, the word 'capitalism' has had too confusing a career . . ..

No, we need to get rid of all categories like those of power, knowledge, profit or capital, because they divide up a cloth that we want seamless in order to study it as we choose. Fortunately, once we are freed from the confusion introduced by all these traditional terms the question is rather simple: how to act at a distance on unfamiliar events, places and people? Answer: by *somehow* bringing home these events, places and people. How can this be achieved, since they are distant? By inventing means that (a) render them *mobile* so that they can be brought back; (b) keep them *stable* so that they can be moved back and forth without additional distortion, corruption or decay, and (c) are *combinable* so that whatever stuff they are made of, they can be cumulated, aggregated, or shuffled like a pack of cards. If those conditions are met, then a small provincial town, or an obscure laboratory, or a puny little company in a garage, that were at first as weak as any other place will become centres dominating at a distance many other places.

(2) The mobilisation of the worlds

Let us now consider some of the means that allow mobility, stability or combinability to improve, making domination at a distance feasible. Cartography is such a dramatic example that I chose it to introduce the argument. There is no way to bring the lands themselves to Europe, nor is it possible to gather in Lisbon or at Versailles thousands of native pilots telling navigators where to go and what to do in their many languages. On the other hand, all the voyages are wasted if nothing except tales and trophies comes back. One of the 'extraordinary means' that have to be devised is to use travelling ships as so many instruments, that is as *tracers* that draw on a piece of paper the shape of the encountered land. To obtain this result, one should discipline the captains so that, whatever happens to them, they take their bearings, describe the shoals, and send them back. Even this is not enough, though, because the centre that gathers all these notebooks, written differently according to different times and places of entry, will produce on the drafted maps a chaos of conflicting shapes that even experienced captains and pilots will hardly be able to interpret. In consequence, many more elements have to be put on board the ships so that they can calibrate and discipline the extraction of latitudes and longitudes (marine clocks, quadrants, sextants, experts, preprinted log books, earlier maps). The travelling ships become costly instruments but what they bring or send back can be transcribed on the chart almost immediately. By coding every sighting of any land in longitude and latitude (two figures) and by sending this code back, the shape of the sighted lands may be redrawn by those who have not sighted them. We understand now the crucial importance of these bundles of figures carried around the world by De Lesseps and the skipper of the *Neptuna*, Captain Martin: they were some of these stable, mobile and combinable elements that allow a centre to dominate faraway lands.

At this point those who were the weakest because they remained at the centre and saw nothing start becoming the strongest, familiar with *more* places not only than any native but than any travelling captain as well; a 'Copernician revolution' has taken place. This expression was coined by the philosopher Kant to describe what happens when an ancient discipline, uncertain and shaky until then, becomes cumulative and 'enters the sure path of a science'. Instead of the mind of the scientists revolving around the things, Kant explains, the things are made to revolve around the mind, hence a revolution as radical as the one Copernicus is said to have triggered. Instead of being dominated by the natives and by nature, like the unfortunate Lapérouse staking his life every day, the cartographers in Europe start gathering in their chart rooms – the most important and costliest of all laboratories until the end of the eighteenth century – the bearings of all lands. How large has the earth become in their chart rooms? No bigger than an *atlas* the plates of which may be flattened, combined, reshuffled, superimposed, redrawn at will. What is the consequence of this change of scale? The cartographer *dominates* the world that dominated Lapérouse. The balance of forces between the scientists and the earth has been reversed; cartography has entered the sure path of a science; a centre (Europe) has been constituted that begins to make the rest of the world turn around itself.

One other way of bringing about the same Copernician revolution is to gather *collections*. The shapes of the lands have to be coded and drawn in order to become mobile, but this is not the case for rocks, birds, plants, artefacts, works of art. Those can be extracted from their context and taken away during *expeditions*. Thus the history of science is in large part the history of the mobilisation of anything that can be made to move and shipped back home for this universal census. The outcome, however, is that in many instances stability becomes a problem because many of these elements die – like the 'happy savages' anthropologists never tired of sending to Europe: or become full of maggots – like grizzly bears zoologists have stuffed too quickly; or dry up – like precious grains naturalists have potted in too poor a soil. Even those elements which can withstand the trip, like fossils, rocks or skeletons, may become meaningless once in the basement of the few museums that are being built in the centres, because not enough context is attached to them. Thus, many inventions have to be made to enhance the mobility, stability and combinability of collected items. Many instructions are to be given to those send around the world on how to stuff animals, how to dry up plants, how to label all specimens, how to name them, how to pin down butterflies, how to paint drawings of the animals and trees no one can yet bring back or domesticate. When this is done, when large collections are initiated and maintained, then again the same revolution occurs. The zoologists in their Natural History Museums, without travelling more than a few hundred metres and opening more than a few dozen drawers, travel through all the continents, climates and periods. They do not have to risk their life in these new Noah's Arks, they only suffer from the dust and stains made by plaster of Paris. How could one be surprised if they start to *dominate* the ethnozoology of all the other peoples? It is the contrary that would indeed be surprising. Many common features that could not be visible between dangerous animals far away in space and time can easily appear between one case and the next! The zoologists *see new* things, since this is the first time that so many creatures are drawn together in front of someone's eyes, that's all there is in this mysterious beginning of a science. As I said in Chapter 5, it is simply a question of scale. It is not at the cognitive differences that we should marvel, but at this general mobilisation of the world that endows a few scientists in frock coats, somewhere in Kew Gardens, with the ability to visually dominate all the plants of the earth.[3]

There is no reason, however, to limit the mobilisation of stable and combinable traces to those places where a human being can go in the flesh during an expedition. *Probes* may be sent instead. For instance, the people who dig an oil rig would very much like to know how many barrels of oil they have under their feet. But there is no way to go inside the ground and to see it. This is why, in the early 1920s, Conrad Schlumberger, a French engineer, had the idea of sending an electric current through the soil to measure the electrical resistance of the layers of rocks at various places.[4] At first, the signals carried confusing shapes back to their sender, as confusing as the first rutters brought back to the early cartographers. The signals were stable enough, however, to later allow the geologists to go *back and forth* from the new electric maps to the charts of the sediments they had drawn earlier. Instead of simply digging oil out, it became possible to accumulate traces on maps that, in turn, allowed engineers to direct the exploration less blindly. An accumulation cycle was started where oil, money, physics and geology helped accumulate one another. In a few decades, dozens of different instruments were devised and stacked together, slowly transforming the invisible and inaccessible reserves into loggings a few men could dominate by sight. Today, every derrick is used not only to pump oil but to carry sensors of all sorts deep inside the ground. At the surface, the *Schlumberger* engineers, in a movable lorry full of computers, are reading the results of all these measurements inscribed on millimetred paper hundreds of feet long.

The main advantage of this logging is not only in the mobility it provides to the deep structure of the ground, not only in the stable relations it establishes between a map and this structure, but in the *combinations* it allows. There is at first no simple connection between money, barrels, oil, resistance, heat; no simple way of tying together a banker in Wall Street, an exploration manager at Exxon headquarters, an electronician specialised in weak signals at Clamart near Paris, a geophysicist in Ridgefield. All these elements seem to pertain to different realms of reality: economics, physics, technology, computer science. If instead we consider the cycle of accumulation of stable and combinable mobiles, we literally *see* how they can go together. Consider, for instance, the 'quick look logging' on an oil platform in the North Sea: all the readings are first coded in binary signals and stocked for future, more elaborate calculations, then they are reinterpreted and redrawn on computers which spew out of the printers logs which are not scaled in ohms, microseconds or microelectrovolts, but directly in number of barrels of oil. At this point, it is not difficult to understand how platform managers can plan their production curve, how economists can add to these maps a few calculations of their own, how the bankers may later use these charts to evaluate the worth of the company, how they can all be archived to help the government calculate the proven reserves, a very controversial issue. Many things can be done with this paper world that cannot be done with the world.

For a Copernican revolution to take place it does not matter what means are used provided this goal is achieved: a shift in what counts as centre and what counts as periphery. For instance, nothing dominates us more than the stars. It seems that there is no way to reverse the scale and to make us, the astronomers, able to master the sky above our heads. The situation is quickly reversed, however, when Tycho Brahe, inside a well equipped *observatory* built for him at Oranenbourg, starts not only to write down on the same homogeneous charts the positions of the planets, but also to gather the sightings made by other astronomers all over Europe which he had asked them to write down on the same preprinted forms he has sent them.[5] Here again a virtuous cumulative circle starts to unfold if all sightings at different places and times are gathered together and synoptically displayed. The positive loop runs all the more rapidly, if the same Brahe is able to gather in the same place not only fresh observations made by him and his colleagues, but all the older books of astronomy that the printing press has made available at a low cost. His mind has not undergone a mutation; his eyes are not suddenly freed from old prejudices; he is not watching the summer sky more carefully than anyone before. But he is the first indeed to consider at a glance the summer sky, plus his observations, plus those of his collaborators, plus Copernicus' books, plus many versions of Ptolemy's *Almagest*; the first to sit at the beginning and at the end of a long network that generates what I will call **immutable and combinable mobiles**. All these charts, tables and trajectories are conveniently at hand and combinable at will, no matter whether they are twenty centuries old or a day old; each of them brings celestial bodies billions of tons heavy and hundreds of thousands of miles away to the size of a point on a piece of paper. Should we be surprised then if Tycho Brahe pushes astronomy further on 'the sure path of a science'? No, but we should marvel at those many humble means that turn stars and planets into pieces of paper inside the observatories that soon will be built everywhere in Europe.

The task of dominating the earth or the sky is almost equalled in difficulty by that of dominating a country's economy. There is no telescope to see it, no collection to gather it, no expedition to map it out. Here again in the case of economics, the history of a science is that of the many clever means to transform whatever people do, sell and buy into something that can be mobilised, gathered, archived, coded, recalculated and displayed. One such means is to launch *enquiries* by sending throughout the country pollsters, each with the same predetermined questionnaire that is to be filled in, asking managers the same questions about their firms, their losses and profits, their predictions on the future health of the economy. Then, once all the answers are gathered, other tables may be filled in that summarise, reassemble, simplify and rank the firms of a nation. Someone looking at the final charts is, in some way, considering the economy. Of course, as we know from earlier chapters, controversies will start about the accuracy of these charts and about who may be said to speak in the name of the economy. But as we also know, other graphic elements will be fed back in the controversies, accelerating the accumulation cycle. Customs officers have statistics that can be added to the questionnaires; tax officials, labour unions, geographers, journalists all produce a huge quantity of records, polls and charts. Those who sit inside the many Bureaus of Statistics may combine, shuffle around, superimpose and recalculate these figures and end up with a 'gross national product' or a 'balance of payments', exactly as others, in different offices, end up with 'Sakhalin island', 'the taxonomy of mammals', 'proven oil reserves' or 'a new planetary system'.

All these objects occupy the beginning and the end of a similar accumulation cycle; no matter whether they are far or near, infinitely big or small, infinitely old or young, they all end up at such scale that a few men or women can dominate them by sight; at one point or another, they all take the shape of a flat surface of paper that can be archived, pinned on a wall and combined with others; they all help to reverse the balance of forces between those who master and those who are mastered.

To be sure, expeditions, collections, probes, observatories and enquiries are only some of the many ways that allow a centre to act at a distance. Myriads of others appear as soon as we follow scientists in action, but they all obey the same selective pressure. Everything that might enhance either the mobility, or the stability, or the combinability of the elements will be welcomed and selected if it accelerates the accumulation cycle: a new printing press that increases the mobility and the reliable copying of texts: a new way to engrave by aquaforte more accurate plates inside scientific texts, a new projection system that allows maps to be drawn with less deformation of shape, a new chemical taxonomy that permits Lavoisier to write down the combinations of more elements, but also new bottles to chloroform animal specimens, new dyes to colour microbes in cultures, new classification schemes in libraries to find documents faster, new computers to enhance the weak signals of the telescopes, sharper styluses to record more parameters on the same electrocardiograms.[6] If inventions are made that transform numbers, images and texts from all over the world into the same binary code inside computers, then indeed the handling, the combination, the mobility, the conservation and the display of the traces will all be fantastically facilitated. When you hear someone say that he or she 'masters' a question better, meaning that his or her *mind* has enlarged, look first for inventions bearing on the mobility, immutability or versatility of the traces; and it is only later, if by some extraordinary chance, something is still unaccounted for, that you may turn towards the mind. (At the end of Part B, I will make this a rule of method, once a crucial element has been added.)

(3) Constructing space and time

The cumulative character of science is what strikes observers so much; why they devised the notion of a Great Divide between our scientific cultures and all the others. Compared to cartography, zoology, astronomy and economics, it seems that each ethnogeography, ethnozoology, ethnoastronomy, ethnoeconomics is peculiar to one place and strangely non-cumulative, as if it remained for ever stuck in a tiny corner of space and time. However, once the accumulation cycle and the mobilisation of the world it triggers are considered, the superiority of some centres over what appear by contrast to be the periphery may be documented without any additional divide between cultures, minds or logics. Most of the difficulties we have in understanding science and technology proceeds from our belief that space and time exist independently as an unshakable frame of reference *inside which* events and place would occur. This belief makes it impossible to understand how different spaces and different times may be produced *inside the networks* built to mobilise, cumulate and recombine the world.

For instance, if we imagine that the knowledge of Sakhalin island possessed by the Chinese fishermen is *included* in the scientific cartography elaborated by Lapérouse, then indeed it appears, by comparison, local, implicit, uncertain and weak. But it is no more included in it than the opinions about the weather are a sub-set of meteorology (see Chapter 5, Part A). Cartography is one network cumulating traces in a few centres which by themselves are as local as each of the points Lapérouse, Cook or Magellan cross; the only difference is in the slow construction of a map inside these centres, a map that defines two-way movement to and from the periphery. In other words, we do not have to oppose the local knowledge of the Chinese to the universal knowledge of the European, but only two local knowledges, one of them having the shape of a network transporting back and forth immutable mobiles to act at a distance. As I said in the Prologue, who includes and who is included, who localises and who is localised is not a cognitive or a cultural difference, but the result of a constant fight: Lapérouse was able to put Sakhalin on a map, but the South Pacific cannibals that stopped his travel put him on *their* map!

The same divide seems to take place between local ethnotaxonomy and 'universal' taxonomies as long as the networks of accumulation are put out of the picture. Can botany, for instance, displace all the ethnobotanies and swallow them as so many sub-sets? Can botany be constructed everywhere in a universal and abstract space? Certainly not, because it needs thousands of carefully protected cases of dried, gathered, labelled plants; it also needs major institutions like Kew Gardens or the Jardin des Plantes where living specimens are germinated, cultivated and protected against cross-fertilisation. Most ethnobotanies require familiarity with a few hundred and sometimes a few thousand types (which is already more than most of us can handle); but inside Kew Gardens, the new familiarity constituted by many sheets of neighbouring herbaries brought from all around the world by expeditions of all the nations of Europe requires the handling of tens and sometimes hundreds of thousands of types (which is too much for anyone to handle). So new inscriptions and labelling procedures have to be devised to limit this number again (see Part B). Botany is the *local knowledge* generated inside gathering institutions like the Jardin des Plantes or Kew Gardens. It does not extend further than that (or if it does, as we will see in Part C, it is by extending the networks as well).[7]

To go on in our journey we should force these immense extents of space and time generated by geology, astronomy, microscopy, etc., back inside their networks – these phentograms, billions of electrovolts, absolute zeros and eons of times; no matter how infinitely big, long or small they are, these scales are never much bigger than the few metre squares of a geological or an astronomical map, and never much more difficult to read than a watch. We, the readers, do not live *inside* space, that has billions of galaxies in it; on the contrary, this space is generated *inside* the observatory by having, for instance, a computer count little dots on a photographic plate. To suppose, for example, that it is possible to draw together in a synthesis the times of astronomy, geology, biology, primatology and anthropology has about as much meaning as making a synthesis between the pipes or cables of water, gas, electricity, telephone and television.

You are ashamed of not grasping what it is to speak of millions of light years?

Don't be ashamed, because the firm grasp the astronomer has over it comes from a small *ruler* he firmly applies to a *map* of the sky like you do to your road map when you go out for a camping trip. Astronomy is the local knowledge produced inside these centres that gather photographs, spectra, radio signals, infrared pictures, everything that makes a trace that other people can easily dominate. You feel bad because the nanometres of living cells baffle your mind? But it means nothing for anyone as long as it baffles the mind. It begins to mean something when the *nanometres* are *centimetres* long on the scaled-up electron photograph of the cell, that is when the eye sees it at the familiar scale and distance. Nothing is unfamiliar, infinite, gigantic or far away in these centres that cumulate traces; quite the opposite, they cumulate so many traces so that everything can become familiar, finite, nearby and handy.

It seems strange at first to claim that space and time may be constructed locally, but these are the most common of all constructions. Space is constituted by reversible and time by irreversible displacements. Since everything depends on having elements displaced each invention of a new immutable mobile is going to trace a different space-time.

When the French physiologist Marey invented at the end of the nineteenth century the photographic gun with which one could capture the movement of a man and transform it into a beautiful visual display, he completely reshuffled this part of space-time. Physiologists had never before been able to dominate the movement of running men, galloping horses and flying birds, only dead corpses or animals in chains. The new inscription device brought the living objects to their desks with one crucial change: the irreversible flow of time was now synoptically *presented* to their eyes. It had in effect become a space on which, once again, rulers, geometry and elementary mathematics could be applied. Each of Marey's similar inventions launched physiology into a new cumulative curve.

To take up an earlier example, as long as the Portuguese carracks disappeared en route, no space beyond the Bojador Cape could be pictured. As soon as they started to reversibly come and go, an ever-increasing space was traced around Lisbon. And so was a new time: nothing before could easily discriminate one year from another in this quiet little city, at the other end of Europe; 'nothing happened' in it, as if time was frozen there. But when the carracks started to come back with their trophies, booty, gold and spices, indeed things 'happened' in Lisbon, transforming the little provincial city into the capital of an empire larger than the Roman Empire. The same construction of a new history was also felt all along the coasts of Africa, India and the Moluccas; nothing would be the same again now that a new cumulative network brought the spices to Lisbon instead of Cairo. The only way to limit this construction of a new space-time would be to interrupt the movement of the carracks, that is, to build another network with a different orientation.

Let us consider another example of this construction, one that is less grandiose than the Portuguese expansion. When Professor Bijker and his colleagues enters the Delft Hydraulics Laboratory in Holland they are preoccupied by the shape that a new dam to be built in Rotterdam harbour – the biggest port in the world – should take. Their problem is to balance the fresh water of the rivers and sea water. So many dams have limited the outflow of the rivers that salt, dangerous for the precious floral culture, is penetrating further inland. Is the new dam going to affect the salt or the fresh water? How can this be known beforehand? Professor Bijker's answer to this question is a radical one. The engineers build a dam, measure the inflow of salt and fresh water for a few years for different weather and tide conditions; then they destroy the dam and build another one, start the measurements again, and so on, a dozen times until they have limited to the best of their ability the intake of sea water. Twenty years and many million florins later, the Hydraulics Lab is able to tell the Port Authority of Rotterdam with a high degree of reliability what shape the dam should have. Are the officials really going to wait twenty years? Are they going to spend millions of florins building and destroying wharfs, thus blocking the traffic of the busy harbour?

They do not need to, because the years, the rivers, the amount of florins, the wharfs, and the tides have been *scaled down* in a huge garage that Professor Bijker, like a modern Gulliver, can cross in a few strides. The Hydraulics Laboratory has found ways to render the harbour mobile, ignoring those features deemed irrelevant, like the houses and the people, and establishing stable two-way connections between some elements of the *scale model* and those of the full-scale port, like the width of the channel, the strength of the flows, the duration of the tides. Other features which cannot be scaled down, like water itself or sand, have been simply transferred from the sea and the rivers to the plaster basins. Every two metres captors and sensors have been set up, which are all hooked up on a big mainframe computer that writes down on millimetred paper the amount of salt and fresh water in every part of the Lilliputian harbour. Two-way connections are established between these sensors and the much fewer, bigger and costlier ones that have been put into the full-scale harbour. Since the scale model is still too big to be taken in at a glance, video cameras have been installed that allow one control room to check if the tide patterns, the wave-making machine and the various sluices are working correctly. Then, the giant Professor Bijker takes a metre-long plaster model of the new dam, fixes it into place and launches a first round of tides shortened to twelve minutes; then he takes it out, tries another one and continues.

Sure enough, another 'Copernican revolution' has taken place. There are not that many ways to master a situation. Either you dominate it physically; or you draw on your side a great many allies; or else, you try to be there before anybody else. How can this be done? Simply by reversing the flow of time. Professor Bijker and his colleagues *dominate* the problem, *master* it more easily than the port officials who are out there in the rain and are much smaller than the landscape. Whatever may happen in the full-scale space-time, the engineers will have *already seen it*. They will have become slowly acquainted with all the possibilities, rehearsing each scenario at leisure, capitalising on paper possible outcomes,

CHAPTER 6

Centres of Calculation

Prologue
The domestication of the savage mind

At dawn, 17 July 1787, Lapérouse, captain of *L'Astrolabe*, landed at an unknown part of the East Pacific, on an area of land that was called 'Segalien' or 'Sakhalin' in the older travel books he had brought with him. Was this land a peninsula or an island? He did not know, that is no one in Versailles at the court of Louis XVI, no one in London, no one in Amsterdam in the headquarters of the West Indies Company, could look at a map of the Pacific Ocean and decide whether the engraved shape of what was called 'Sakhalin' was tied to Asia or was separated by a strait. Some maps showed a peninsula, others showed an island; and a fierce dispute had ensued among European geographers as to how accurate and credible the travels books were and how precise the reconnaissances had been. It is in part because there were so many of these disputes – similar to the profusion we studied in Part I – on so many aspects of the Pacific Ocean, that the king had commissioned Lapérouse, equipped two ships, and ordered him to draw a complete map of the Pacific.[1]

The two ships had been provided, as scientific satellites are today, with all the available scientific instruments and skill; they were given better clocks to keep the time, and thus measure the longitude more accurately; they were given compasses to measure the latitude; astronomers had been enlisted to mend and tend the clocks and to man the instruments; botanists, mineralogists and naturalists were on board to gather specimens; artists had been recruited to sketch and paint pictures of those of the specimens that were too heavy or too fragile to survive the return trip; all the books and travel accounts that had been written on the Pacific had been stocked in the ship's library to see how they compared with what the travellers would see; the two ships had been loaded with goods and bargaining chips in order to evaluate all over the world the relative prices of gold, silver, pelts, fish, stones, swords, anything that could be bought

Chapter 5

1 See David Bloor (1976). On this debate see M. Hollis and S. Lukes (1982) and E. Mendelsohn and Y. Elkana (1981). The two most interesting articles on this debate are without doubt those of R. Horton (1967; 1982).
2 This example from E. E. Evans-Pritchard's classic book (1937) has been turned into a canonic topic for anthropology of science by David Bloor (1976).
3 This example is taken from Edward Hutchins (1980).
4 I am following here D.A. Hounshell (1975).
5 See on this succession of contradictory accusations B. Easlea (1980).
6 See on this point B.J.T. Dobbs (1976).
7 This is an adaptation of D. Bloor's drawing (1976, p. 126).
8 Naturally, I am following here the canonic example offered by Bloor and not the very subtle interpretations offered by Evans-Pritchard.
9 See on this point the classic book edited by B. Wilson (1970).
10 I am following here M. Cole and S. Scribner (1974); other examples by A.R. Luria are to be found in his (1976) book edited by M. Cole.
11 This other canonic example is taken from R. Bulmer (1967) and has been treated at length by B. Barnes (1983).
12 The most complete work of ethnoscience is to be found in H. Conklin (1980). Unfortunately there is no equivalent of this on a Western industrialised community.
13 I am using here the beautiful book of A. Desmond (1975), especially the chapter 6.
14 This example is taken from M. Callon (1986).
15 His testimonies form the bulk of M. Augé's book (1975). For obvious reasons, Augé never published the result of the corpse interrogation of his friend.
16 This example is taken from J. Gusfield's book which is a unique case of anthropology of belief/knowledge in a modern Western society (1981).
17 This is why 'oral cultures' have been thought to be both rigid and devoid of innovation. On this see J. Goody's pioneering work (1977).
18 On this transformation and transportation of other people's beliefs see P. Bourdieu (1972/1977) J. Fabian (1983) and the recent book on field trips edited by G.W. Stocking (1983).

Chapter 6

1 On this episode see J.-F. Lapérouse (no date) and F. Bellec (1985).
2 I am following here J. Law's account of this episode (1986). On all this redefinition of capitalism in terms of long distance networks the essential work is of course that of F. Braudel (1979/1985).
3 The literature on expeditions and collections is not very extensive but there are some interesting case studies. Among them are L. Brockway (1979) and L. Pyenson (1985).
4 This example is taken from L. Allaud et M. Martin (1976).
5 I follow here E. Eisenstein's account (1979). Her book is essential reading for all of those who wish, as she says, to 'reset the stage for the Copernician Revolution'.
6 For a general review of this question see the volume I edited in French with J. de Noblet (1985).
7 On this comparison between botanists and ethnobotanists see H. Conklin (1980).
8 I follow here B. Bensaude-Vincent's account (1986). See also her thesis (1981) and on Mendeleev's work see F. Dagognet (1969).
9 Actually, the strength of the table came later from the unexpected correspondence between the classification and the atomic theory that retrospectively explained it.

10 This example is elaborated in M. Polanyi (p. 83).
11 For an interesting study see that of F. Fourquet (1980) on the construction of INSEE, the French institution gathering statistics.
12 See P.S. Stevens (1978). On this question of the relations between scale models, models and calculations, probably the best book is still M. Black (1961). Less known but very useful is the work of F. Dagognet. See in particular is recent book (1984).
13 I am following here the exemplary article of T. Hughes (1979).
14 This useful word has been proposed by E. Gerson and L. Star to describe much the same mechanism as the one I name here 'cascade'. This chapter owes much to the work of their Tremont Institute in California.
15 This does not mean that 'theories' simply follow the accumulation of 'data' – on the contrary 'mere stamp collecting' is often opposed to 'real science' – but simply that any a priori epistemological distinction between the two makes the study impossible. The problem is that we lack independent studies on the construction of this contrast between 'data' and 'theories'. For such an endeavour on the relations between physics and chemistry see I. Stengers (1983).
16 See on this A. Koyré (1966) and S. Drake (1970).
17 This has to be taken with a grain of salt since there is no study pertaining to anthropology of science which tackles this question. A related effort is to be found in E. Livingston's recent book (1985).
18 I am using here the excellent book of T. Wolfe (1979). To the humiliation of our profession, we have to confess that some of the best books on technoscience, those of Kidder, Watson and Wolfe, for example, have not been written by professional scholars.
19 This example is taken from one of the rare long-term, empirical studies of a modern large-scale technical project by M. Coutouzis (1984); see also our article (1986) (Coutouzis and Latour).
20 On this episode see J. Geison (1974).
21 See the article by P. Hunter (1980).
22 Within the small but fascinating literature on this topic, the best introduction is the work of P.J. Booker (1979) and Baynes K. & Pugh F. (1981). For a shorter introduction see E. Ferguson (1977).
23 On this dispersion of the sciences as on so many microtechnics of power see M. Foucault's work, especially (1975).

SOURCES - TEXT

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Atelier Bow-Wow . “Architectural Behaviorology”, in: id: Behaviorology, Rizzoli International Publications, 2010, pp 8-15.

B. Latour. “Opening Pandora’s Black Box“, in: id: Science in Action, Cambridge, 1987, pp 1-17, pp 215-265.

SOURCES - IMAGES

Fig. 01: Atelier Bow-Wow, Momoyo Kaijima (2021). Architectural Ethnography Drawing version 5

Fig. 02: Diploma FS21 24/7 Metropolitan Hybrid Machine. Oliver Brunhart, ETHZ. Actor Network Drawing

Fig. 03: HS19. Yuni Zhao, ETHZ. Actor Network Drawing

Fig. 04: BUK. Käferstein & Meister Architekten, Haus in Küssnacht

Fig. 05: BUK.

Fig. 06: R. Masats (1955). Retrieved on 31.08.2021: https://www.theguardian.com/artanddesign/gallery/2020/jul/15/behind-the-bullfighters-ramon-masats-spain-in-pictures#img-8

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