patterns are not to be explained by their society: the) are the right way. They will call ethnozoology the belief systems of the local Karam and zoology the knowledge of the universal scientific network. Although each sociologic is building its world by incorporating birds, plants, rocks, together with people, it will appear, at the end of many trips abroad, that only 'They' have an *anthropomorphic* belief system, whereas `We' have a disinterested outlook on the world only slightly biased by our `culture'. In Figure 5.5 I have sketched two possible renderings of the differences: the first one is obtained by tracing *a* Divide between Them and Us; the second by measuring *many* variations in the size of the networks. The Great Divide makes the supposition that there is, on the right hand, knowledge embedded in society, and, on the left hand, knowledge independent of society. We make no such supposition. The general fusion of knowledge and society is the same in all cases - a spiral in the diagram - but the length of the curve varies from one to the other.

'Interest' and 'disinterestedness' are words like 'rational' or 'irrational'; they are meaningless as long as we do not consider the movement of the scientist through the world. This will constitute our **sixth rule of method:** when faced with an accusation of irrationality, or simply with beliefs in something, we will never believe that people believe in things or are irrational, we will never look for which rule of logic has been broken, we will simply consider the angle, direction, movement and *scale* of the observer's displacement.

Of course, now that we are freed from all these debates about 'rationality', 'relativism', 'culture', and the extent of the Great Divide, we have one more question to tackle, the most difficult of all: where does the difference of scale come from?

((214))

((215))

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 millennia. 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

sociologies 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

xxx figur 6.1 start xxx

Figure 6.1

Figuren likner figur 5.5 (s. 211), bortsett fra at figur 6.1 vektlegger akkumulasjon av kunnskap.

Ett punkt er markert med en sirkel. Piler går i en bue ut fra denne, gjør en sving, og kommer tilbake til start. Underveis passerer pila forbi mange konturer av mennesker, som enten står i klynger eller hver for seg. Sirkelen er "sentralen", pilene er ekspedisjoner som utgår fra denne.

Ved pilene står det: "Crossing other people's path"

I det pilene legger ut på sin reise fra startpunktet, står det "Going away".

I det pilene er på vei tilbake til startpunktet, står det: "Coming back".

Pil nr. 1, første ekspedisjon, forsvinner i felten og kommer ikke tilbake. Informasjonen som sentralen får av denne ekspedisjonen (X1) er temmelig ubrukelig.

Pil nr. 2 legger ut på samme reise, og kommer tilbake til sentralen med ny informasjon fra ekspedisjonen (X2).

Pil nr. 3 legger ut på en lengre reise, på grunnlag av informasjonen X2, og kommre tilbake til sentralmakten med enda mer informasjon fra ekspedisjonen (X3).

xxx figur 6.1 slutt xxx

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 thé 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

((222))

the *Regimen to doAstrolabio 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.

((223))

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

((224))

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 `Copernican 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 Copernican 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 any-thing 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 sent 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

((226))

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 ,'

((229))

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?

((230))

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 modem 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,

((232))

which gives them years of experience more than the others. The order of time and space has been completely reshuffled. Do they talk with more authority and more certainty than the workmen building the real dam there? Well, of course, since they have already made all possible blunders and mistakes, safely inside the wooden hall in Delft, consuming only plaster and a few salaries along the way, inadvertently flooding not millions of hard-working Dutch but dozens of metres of concrete floor. No matter how striking it is, the superiority gained by Professor Bijker over the officials, architects and masons about the shape of the dam is no more supernatural than that of Marey, of the Portuguese or of the astronomer. It simply depends on the possibility of building a different space-time.

We now have a much clearer idea of what it is to follow scientists and engineers in action. We know that they do not extend 'everywhere' as if there existed a Great Divide between the universal knowledge of the Westerners and the local knowledge of everyone else, but instead that they travel inside narrow and fragile networks, resembling the galleries termites build to link their nests to their feeding sites. Inside these networks, they make traces of all sorts circulate better by increasing their mobility, their speed, their reliability, their ability to combine with one another. We also know that these networks are not built with homogeneous material but, on the contrary, necessitate the weaving together of a multitude of different elements which renders the question of whether they are 'scientific' or 'technical' or 'economic' or 'political' or 'managerial' meaningless. Finally, we know that the results of building, extending and keeping up these networks is to act at a distance, that is to do things in the centres that sometimes make it possible to dominate spatially as well as chronologically the periphery. Now that we have sketched the general ability of these networks to act at a distance and portrayed the mobilisation and accumulation of traces, there are two more problems to tackle: what is done *in* the centres and *on* the accumulated traces that gives a definitive edge to those who reside there (Part B); and what is to be done to maintain the networks in existence, so that the advantages gained in the centres have some bearing on what happens at a distance (Part C).

Part B. Centres of calculation

After having followed expeditions, collections and enquiries, and observed the setting up of new observatories, of new inscription devices and of new probes, we are now led back to the centres where these cycles started from; inside these centres, specimens, maps, diagrams, logs, questionnaires and paper forms of all sorts are accumulated and are used by scientists and engineers to escalate the proof race; every domain enters the 'sure path of a science' when its spokespersons have so many allies on their side. The tiny number of scientists is more than balanced by the large number of resources they are able to muster. Geologists can now mobilise on their behalf not a few rocks and a few nice water

((233))

colcurs of exotic landscapes, but hundreds of square metres of geological maps of different parts of the earth. A molecular biologist, when she talks of mutations in maize, may now have at her side not a few wild cobs, but protocol books full of thousands of cross-breeding results. The directors of the Census Bureau now have on their desks not only newspaper clippings with opinions on how big and rich their country is, but stocks of statistics extracted from every village that array their countrypeople by age, sex, race and wealth. As for astronomers, a chain of radio-telescopes working together transforms the whole earth into one single antenna that delivers thousands of radio sources through computerised catalogues to their offices. Every time an instrument is hooked up to something, masses of inscriptions pour in, tipping the *scale* once again by forcing the world to come to the centres — at least on paper. This mobilisation of everything that can possibly be inscribed and moved back and forth is the staple of technoscience and should be kept in mind if we want to understand what is going on inside the centres.

(1) Tying all the allies firmly together

When entering the many places where stable and mobile traces are gathered, the first problem we will encounter is how to *get rid of them.* This is not a paradox, but simply an outcome of the setting up of instruments. Each voyage of exploration, each expedition, each new printer, each night of observation of the sky, each new poll, is going to contribute to the generation of thousands of crates of specimens or of sheets of paper. Remember that the few men and