

## THE FORCE AND THE REASON OF EXPERIMENT

For Françoise Bastide. In memoriam

### 1. ARCHIMEDES ON THE BEACH

Archimedes, who was a kinsman and friend of King Hiero, wrote to him that with any given force it was possible to move any given weight; and emboldened, as we are told, by the strength of his demonstration, he declared that, if there were another Earth, and he could go to it, he could move this one. Hiero was astonished and begged him to put his proposition into execution, and show him some great weight moved by a slight force. Archimedes therefore fixed upon a three masted merchantman of the royal fleet, which had been dragged ashore by the great labours of many men, and after putting on board many passengers and the customary freight, he seated himself at a distance from her, and without any great effort, but quietly setting in motion with his hand a system of compound pulleys, drew her towards him smoothly and evenly, as though she were gliding through the water. Amazed at this, then, and comprehending the power of his art (*sunnoesas tes tecnes ten dunamin*), the King persuaded Archimedes to prepare for him offensive and defensive engines to be used in every kind of siege warfare. (Plutarch, 1961: xiv, 78-9)

In this famous report of what may be the oldest public scientific experiment, several features are remarkable. The performance has almost certainly never been staged (at least with a fully loaded ship);<sup>1</sup> it is thus a *tale* of a staged thought experiment, but a story which for hundreds of years played a continuous role in shaping the relations between Kings, mathematics, war and mechanics. It is a public show before all the assembled 'media'. It is a direct application of a theoretical demonstration that Archimedes had just completed following a Platonist research program that Plutarch sketches in the paragraph before. It is Archimedes himself who takes the initiative of boasting to the King that he can move the Earth; the King, quite reasonably, challenges him to a 'show down' by way of a smaller scale public experiment before believing in the demonstration, as if he was unable to be convinced by the strength of mathematics alone; but it is the King who, in an instant, makes the connection of this striking but futile experiment with a technical and military research program headed by Archimedes (*o demiurgos*) to protect Syracuse against the Romans.

But, why was Archimedes so emboldened by his apodeictic demonstration that he could move the planet and why was Hiero so amazed by the smaller scale show, impressed (as the text tells us) by the power of technique? Because 'some great weight may be moved by a slight force'. Is it possible to reverse the age old balance of forces? Can one man become stronger than the multitude? And this, not just ideally in a thought experiment about going to another planet and moving the Earth, but in practice, on the beach. Where the labour of many sailors and slaves had been necessary to move the ship ashore, the arm of an old, dignified free man was sufficient. A multitude becomes less strong than one, provided you add to one's inner workings a system of compound pulleys. Is this not quite sufficient to appeal to Hiero? A king is never physically superior to the multitude he commands. Archimedes, the physicist, is physically superior to the multitude because he knows how to balance proportions over a fulcrum. This reversal of force is of enormous importance for Hiero and since then for every Prince seduced by a Star Wars program.

According to Plutarch (xvii, 4-5), however, Archimedes himself is much more struck by another reversal:

And yet, Archimedes [after equipping Syracuse with war machines] possessed such a lofty spirit, so profound a soul, and such a wealth of scientific theory, that although his inventions had won for him a name and fame for superhuman (*ouk anthropines*) sagacity, he would not consent to leave behind him any treatise on this subject, but regarding the work of an engineer and every art that ministers to the needs of life as ignoble and vulgar, he devoted his earnest efforts only to those studies the subtlety and charm of which are not affected by the claims of necessity.

Back to fundamental research. After a little detour through wizardry, demiurgy and weaponry -- like Szilard, Einstein and so many others since -- Archimedes goes back to geometry, to this extraordinary Planet War in which apodeictic reasoning can *reverse* the multitude of objections that common sense, the senses, tradition and normal decency bring against it. To be sure, he accepts Hiero's challenge, but this staged experiment is nothing compared to being able to *demonstrate* that any one weight could lift any other, no matter how big or to prove *against* all contrary evidences that he could move the Earth. This is what, in a Platonist world, really counts.

In this famous text which marks the start of Science, Technology and Society studies, there are four reversals of forces, each compounding the other. First, he, Archimedes, in a somewhat paranoid thought-experiment, could move the Earth provided he had a lever and a firm point. This is the origin of all the demiurgic dreams of scientists. Second,

the power of a mathematical demonstration is greater than that of all other contrary experimental, political, or common sense evidence. This is the origin of the distinction between rhetoric or sophistics on the one hand and apodeictic reasoning on the other. Third, a well designed piece of machinery may reverse the balance of forces and change for ever the face of the Earth. This lesson will not be lost on long lineages of Princes and Engineers who will enlist non-humans on their sides to win over the multitude of humans. But, fourth, all the little gadgets that empirical sciences may produce are nothing compared to the pursuit of disinterested and unnecessary knowledge. As a good Platonist, Plutarch shows all the scientists of the future how a little bit of abstract reasoning can be made more valuable, more real and more weighty than any earthly achievements. We could perhaps add a fifth reversal: a tale of an experiment that stages the demiurgic power of a scientist is stronger than any historical account showing the contrary. This is still felt by historians of science.

If you combine these four reversals of forces as intricately as the pulleys attached to the merchantman, you may at once do politics without doing any, build machines without building any, strike this world and its masses without ever leaving the world of ideas. Indeed, it is the very notion of a Platonic Idea that sums up all the ultimate reversals of forces to which Archimedes and Plutarch are subscribing: give me the Idea, the noumen, and I will move the world, the phenomenon; give me the essence of man, what Man is, and I will have more, know more, weigh more, than if all the empirical, real, unreal, shadowy, empirical men and women were given to me. What we admire in Platonism, this audacious reversal of reality and common sense, we should admire in a lever or, for that matter, in an atomic explosion.

The extraordinary power of Archimedes' demonstration is to render *commensurable* and *continuous* through a law of proportion the small and long arms of the lever. But, the extraordinary power of Plutarch's demonstration is to claim that although the science of the scientists and the politics of the King are made at once continuous and commensurable, they are nevertheless transformed, through a law of *disproportion*, into an absolute *incommensurability* between the world of Reason and the world of Forces. For Plutarch a mathematical demonstration is not in continuity with a political demonstration, a show of strength, even though it reverses the outcome of any show of strength. Plutarch strikes twice, not just once: Archimedes sees that the only basic difference between the light and the heavy, the single and the many, the weak and the strong, is a law of proportion. This is enough to surprise

the King and his retinue who believe in the reality of all those differences, but then Archimedes traces a yawning gap between the base world of the demonstration of forces and the high spiritual world of the demonstration of reason. This is enough to strike the King and his followers who started to believe in the continuity of politics and science! This is what makes this text so exemplary for a study of science and society.

When and where does Plutarch talk about politics? When Hiero comes into the story challenging Archimedes? When Hiero concludes the public experiment with a micro Manhattan project? Yes, but not just then. Politics comes into the picture before: when Plutarch explains why ideal mathematics are *superior* to vile empirical means (xiv, 3-6); politics is there when Archimedes' arm balances the weight of the fully laden trireme; and politics is still there when Plutarch, Plato and Archimedes contemptuously erase all traces of mechanical gadgets and earthly mechanics to return to a world that is infinitely stronger than this base one. If politics were limited to Kings and people, then there would be no need for public experiment, for compound pulleys, and for abstract demonstrations. But if politics consist in reversing the balance of forces, in reshuffling the definition of who is stronger than whom, nay, if politics consist, since Archimedes, *to compose, mix and confuse, to make both commensurable and incommensurable various balances of forces*, then we understand why Archimedes is on the beach this beautiful Sicilian afternoon, applauded by the crowd, baffling the King with *tes tecnes ten dunamin* [See Figure 1].

'He declared that, if there were another world, and he could go to it, he could move this one'. Well, he does have this other world, he lives in it, and it is from here that he moves the merchantman, the King, the Syracusans, Marcellus, and the whole lot. This is the world of science. It is the world of Ideas where Archimedes is firmly entrenched, his fulcrum at hand, experimenting on how to move our world. The Platonist realm so much vaunted and so much denounced, is not spiritual, is not detached from ours. Rather they are in continuity, they bear the same relation to each other as the little weight on one arm of a scale to the vastly greater weight that is balanced out on the other side. In our admiration (or our hate) for Platonist Ideas, we too often forget that it is first of all a fantastic machinery to reverse all relations of forces by tying science and politics in a huge 'minimax' relation. A vastly stronger force *is* a force. A force which is so different that it is not even engaged in the base politics and technics it can reverse at will, is a force all the more so.<sup>2</sup> The whole mystery of the field of Science,

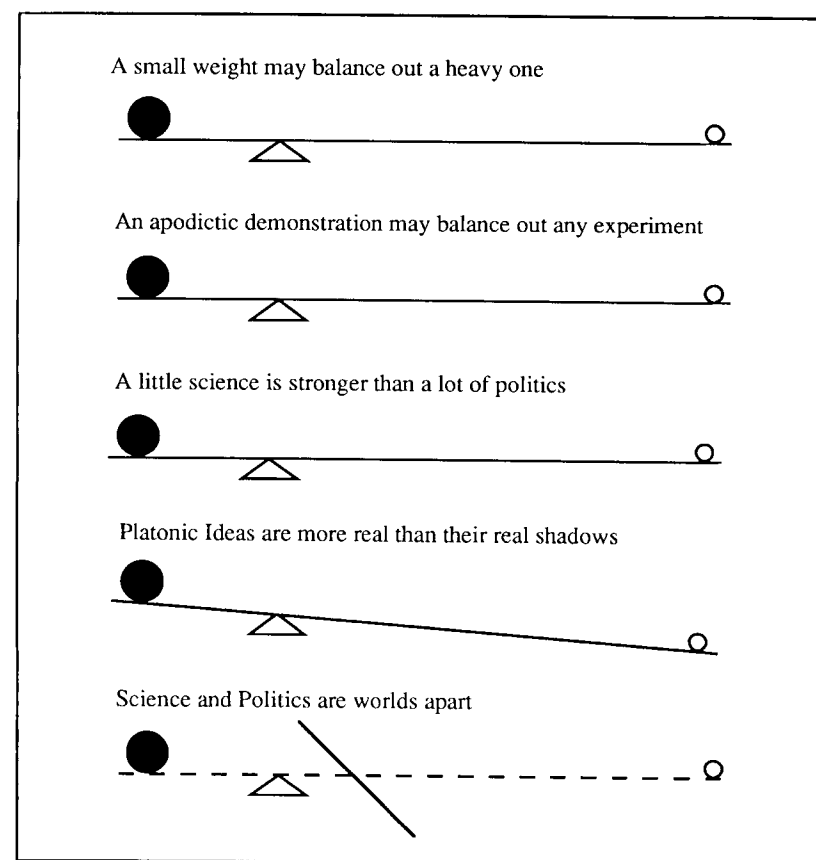


FIGURE 1

Technology and Society Studies hinges on this balance of forces made continuous and discontinuous, commensurable and incommensurable at the same time.

## 2. PERON ON THE TASMANIAN SHORE

Baudin, the French explorer, more fortunate than Archimedes, goes from worlds to worlds, and together with many Cooks and La Perouses, allow the European nations, through the tiny lever of geography,

sailboats and expeditions, to raise quite a bit of this Earth. Peron, the official zoologist of the 1802 Baudin expedition, is a closet anthropologist mostly concerned with interviewing wary aborigines on the beach as a way of solving questions raised by Rousseau about the inherent goodness of the Noble Savage:

I then wanted to try to make use of the dynamometer I had brought with me. I thought that the form of the instrument and the way of using it would perhaps attract their attention and occupy them for a few moments. I was not mistaken. They admired the instrument, all wishing to touch it at the same time, and I had most difficulty in preventing them from breaking it. By making repeated trials with it in their presence, they seemed to understand how to use it, and already four had done so, and I was hoping that all the rest would follow their example, when the old man of whom I have spoken and who until then had remained silent, retaining always on his face a profound look of misgiving, distrust and wariness, uttered a few words which, without having the air of being precisely an order, produced however an effect such that no one of them dared to touch the instrument again. Undoubtedly it would be difficult to know precisely what this old man actually said to his compatriots, but from the attention he had given to everything I happened to do with the dynamometer, it was evident he had understood its use perfectly. Then, reflecting on the object we could have for such an operation, his reason and experience had been able to tell him: 'without doubt, these strangers only wish to test our strength in order to use the information they acquire against us in future'; and his compatriots, whom he made acquainted with his reflections, having understood that his suspicions had a real foundation, did as he wished, seeming even to keep up some resentment about what I was doing' (Plomley, 1983: 89)

The aborigines become still more restless when Peron, abandoning the suspect dynamometer and hoping to calm them, reverts to the classical barter system and starts exchanging spears for beads and bottles. The anthropological interview soon turns into a show of force that would not have favoured Peron had it been pursued (90-1):

The old man had filled the hearts of all with his suspicions and his fears: 'These treacherous strangers,' he must have said to them, 'want to know your strength only so as to come afterwards to oppress you by the strongest possible means.' Such talk could not fail to excite against us a general mistrust, and this mistrust seemed to become certainty from the moment when we sought to obtain their weapons *at great cost*. After that it seemed we were only seeking to deprive them of them, so as to strengthen the execution of our treacherous designs.

Even if Peron grant the old man a conception of a balance of power and strength relations which is unthinkable for the aborigines, the way he aligns the dynamometer and the exchange of goods -- micro-scale experiments -- inside the bigger scale experiment of European exploration is most revealing of *his* notion of power. Just as Baudin's ship tests the relative strength of the coastline, inscribing on a map the

movement of their ship (and hardship) to decide what is worth knowing, having and colonizing, Peron tests the relative strength of the savages he meets to decide whether or not civilisation is a degradation or an improvement. Every navigator does the same by bartering goods, trinkets and trophies to test the relative value of everything on earth compared to everything else. Peron does not try to hide the link between his objective science, the market forces, and the objectives of the expedition. Not only does he tie them to one another but he *grants* the aborigines the *same* appraisal. They too are portrayed as sociologists of science seeing a power relation beneath the data and the exchange. To do so they are helped by the fact that the dynamometer itself -- wrists or loins against lever and needles -- and the barter system, spears for bottles -- are literally relations of strength.<sup>3</sup> Peron's assessment of the situation or the assessment he supposes is being made by the old man, are both quite extraordinary given that neither could predict in 1802 that this little experiment would end up by wiping out the Tasmanians altogether. Before colonization has even started, the story is terminated by Peron and attributed to the foreknowledge of the savage. 'They will oppress you by the strongest possible means'. This little island will indeed be moved by the fulcrum of civilization, but the aborigines will not follow the movement. They will be shaken out.

But, in the report that Peron writes in his *Voyage*, it is the Noble Savage thesis that is wiped out much more quickly than the real savages. In his chapter entitled 'Experiments on the savage people of New Holland', Peron (150), after comparing Tasmanians with French and English sailors, is forced to conclude that Native Man is weaker than Civilized Man: 'the inhabitants of Van Diemen's Land [Tasmania], the most savage of all, *the true children of nature*, are the most feeble' (Peron's italics). 'That memorable epoch has not so long passed when we saw celebrated men, trapped within a vivid imagination and embittered by the misfortunes inseparable from our social condition, denounce it because they failed to recognize the benefits, and reserve for the savages all sources of happiness and all virtuous principles' (146). Here goes Rousseau, forced outside the debate by the strength of Regnier's dynamometer and the computation of Peron's measurements. In addition to the spring and needle of the dynamometer, in addition to the cartographic expedition of Baudin, there is a third balance of forces, that between arguments. Rousseau speaks without data. Peron has the data behind him expressed in kilograms. He has been there. He has tried the dynamometer on the beach and recorded the readings, although not as many as he wished because of the savage's critical

sociology of science. Experimental anthropology should replace the weaker discourse of philosophers as surely as the settlers should displace the weaker aborigines.

This anecdote allows us to see the difference between being *experienced* and being an *experimenter*. Dozens of navigators had experienced the coast of Australia, mostly by dying on her reefs; dozens of sailors had experienced the savages by marrying them, killing them, selling them or being pierced by their spears. The skill, knowledge, and know-how thus acquired exists, but incorporated, embodied in the very flesh of the experienced person. Bits and pieces of Terra Australis started to be experimented upon, when experienced navigators recorded each encounter in a common written or visual language and shipped these records to a common place where they could be gathered and combined. But instead of being incorporated, their skill, knowledge and know-how is *excorporated*, inscribed and turned into papers and maps piling up inside the walls of some scientific or commercial or political institution. You have to have been *through* the trial and then *out* of it. Before and after this slight shift from body to inscription, sailors suffer hardship, wreck their boats, die of dysentery, and feel the exhilarating beauty of the Tasmanian coastline. Before and after they are tried by the coast and by the natives. But, now they have turned their bodies, their crew, their ship into the inked needle of an instrument of enormous proportions that scribbles the shape of Van Diemen's Land in London, Paris or Den Hagen. And while they are recording the shape of the land, even before shipping it to Europe, in the crowded cabin of their boat, surrounded by stuffed specimens of birds and dried plants, they are using this freshly made inscription to make points against their colleagues, Captain Cook, Marion Du Fresnes or Rousseau with whose work they have surrounded themselves. Peron, like all the scientific navigators of the late eighteenth and nineteenth centuries is travelling both *to* Tasmania and *within* the scientific literature. He cannot record a piece of data on his dynamometer without seeing the article he is going to write reversing the point made by another writer, back there in France, about the Theory of the Noble Savage. Each recorded experiment is fodder for thought, for the agonistic field back home.

This is why there is so little difference between *observation* and *experiment*, as often noted by Claude Bernard. An observation is an experiment where the body of the scientist is used as instrument, complete with its writing device, that is, a hand, a quill and a notebook. Peron, before testing the strength of the Tasmanians and the quality of their sociology of science, undergoes all sort of trials in the aborigines'

hands. He barely avoids exposing his most intimate parts. After a sailor had performed a few sleights of hand, a savage pierces him with a needle to see if blood comes out. He allows them to smear him with charcoal. 'We were so novel to one another! The natives wanted to examine the calves of our legs and our chests, and so far as these were concerned we allowed them to do everything they wished, oft repeated cries expressing the surprise which the whiteness of our skin seemed to arouse in them' (84). When undergoing these trials, Peron *notes, records and writes*; his colleague, Petit, *draws and paints*. The savage tests the whites' testes, but they do not write down the result, let alone make every effort to send it away. He, Peron, availing himself of his new friends' nakedness, writes a long chapter on the absence of erection among the Tasmanians! Both parties gain knowledge through experience. But, while the savage gains experience of the white man, the scientists, offering their bodies to science, turn themselves into an object of experiment. It does not matter if he has an instrument -- the dynamometer, his own body -- prodded by the savages whose reactions he registers accurately, his eyes -- trained, biased and disciplined, or the huge laboratory-like paraphernalia of clocks, projective geometry and cartography that Baudin carries on board. Only three things matter: that there is a trial, that there is an inscription, that there is a point in the literature to be made or unmade. With these three things taken together Peron is confident that his time and the money of the doomed Republic has not been wasted, that Rousseau's Noble Savage argument can be put to rest, and that his data will back him up in case of controversy.<sup>4</sup>

This iron tie between trials, inscriptions and fields is more important than all minor distinctions between experiments that are man-made and observations that are supposed to confront phenomena on which man has no control -- coastlines, stars or dancing cranes, or with field expeditions in the open and expeditions of probes and meters inside the protected walls of a laboratory. One could say that Tasmania is 'observed' by Baudin and that the strength of savages is 'experimented upon' by Peron, because the former is merely sighted without being manipulated, whereas the latter is a highly elaborated construction depending on dynamics, instruments, protocol and (inaccurate) statistics. This, however, would be a misleading distinction since the whole of Baudin's expedition is the moving and registering part of a larger instrument whose 'screen' or window is set up in Paris, and whose data are feeding various discussions on the size of the strait between New South Wales and Tasmania or on the possible colonization of South Australia. These gentlemen back in Paris experiment on what the Earth

looks like, they bet and theorize, waiting for the results of the expedition, as surely as if they were microbiologists in their laboratories waiting for a culture to grow. It only happens that their laboratory has the size of the Earth, and that the probe they send away is manned by men and relies a lot on disciplined eyesight, but it could be an unmanned satellite, or a core drilling.

Visually, the inscribed results brought back from an expedition, from an observation, or from an experiment look alike and this is what counts in feeding the discussion.<sup>5</sup> They 'refer to' which means, etymologically, that they 'bring back' things. Archimedes was building a continuous relationship between the small and large weights, through the calculated proportion of the lever. Each instrument builder, each expedition, each experimenter sets up a balance very similar in shape to Archimedes' enterprise: the small paper-like window of the inscriptions balances out what it refers to -- the vast world 'out there' -- through the maintenance of certain proportions (Latour: 1986) [See Figure 2]. Anthropologists,

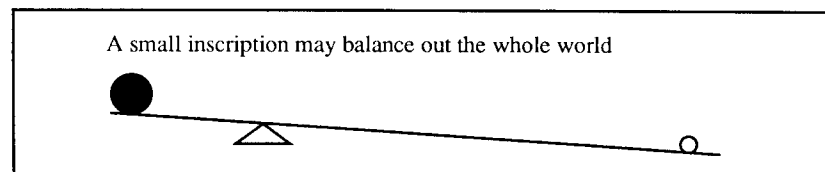


FIGURE 2

geographers and zoologists in Paris can now indulge the two favourite gestures of realist philosophers, *i.e.* thumping the table ('this is a hard fact!') and pointing at details with their index finger (the other meaning of reference). But, what they point to and thump on are the *inscriptions* brought back through whichever means the ingenuity of scientists has invented. In the aula of the Institute, in the cabinet of the Societe des Observateurs de l'Homme, there will be discussions about these thin and delicate pieces of paper, and it will be as if they were talking on, and talking of the Tasmania shore, not thumping on their table but on the beach, not pointing at the statistics but at *this* old aborigine himself. The inscriptions are only the thin, almost immaterial, sharp end of a huge instrument. And as miraculously as on the Syracusan beach, the gentlemen shuffling around this side of the lever will be able to reverse the 'vastly superior' forces of Tasmania and the Tasmanians.

However, for this new balance of power to be enforced, it is necessary for the overall apparatus to possess another paramount

property: the traces that are brought back must not be *made-up*. Baudin has to prove that he has been there. Peron has to prove that he has been there. No matter if they deal with man-made or naturally occurring phenomena, no matter if they deal with phenomena inside or outside the laboratory, what counts is that the human discussant has behind him data that do not depend on man. How can this unreliable and querulous political animal introduce into the discussion things that are non political, that are reliable, and that put discussions to an end?

### 3. PASTEUR ON THE VERGE OF FERMENTATION

Thus, there was a great interest in deciding whether racemic acid would undergo the same fermentation as the right tartrate acid, in other words, whether the yeast would transform the left tartrate acid as readily and in the same way as the right tartrate acid. The ammonium racemate was fermented in the same manner as I indicated above for the right tartrate. The fermentation manifested itself as easily, with the same characteristics and deposit of yeast. But in following the development of this phenomenon with a polarizer, it was clear that things are altogether different. After a few days of fermentation, the liquid that was at first inactive, now possesses a discernible rotary power on the left, and his power increases progressively during the fermentation until it reaches a maximum. At which point fermentation is then stopped. There is not a trace remaining of right acid in the liquor which, once evaporated and mixed to its volume of alcohol, provides at once an abundant crystallization of left ammoniac tartrate.

No doubt this offers an excellent means to prepare left tartrate acid. But the whole interest of this fact seems to me to depend on the physiological role of fermentation which appears, in my experiments, as a phenomenon pertaining to the vital order. We see here that the character of molecular dissymmetry so peculiar to organic matters intervenes to modify the affinity. There is no doubt that it is the type of dissymmetry characteristic of the molecular arrangement of the left acid tartrate that is the only and exclusive cause of the non-fermentation of this acid in the very conditions where the symmetric acid is destroyed.<sup>6</sup>

In his laboratory in Strasbourg, Pasteur is *designing* an actor, an actor as new as the exact shape of the Tasmanian coast designed, drawn together, by Baudin's expedition. How does he do this? By defining trials for the actor to show its mettle -- a metaphor coming from another trial of strength. Why is an actor defined through trials? Because, there is no other way to define an actor other than through its action and there is no other way to define an action but by asking what other actors are modified, transformed, perturbed, or created by the character that is made the focus of attention (Latour: 1988). This is a pragmatist tenet, which is extended to the thing itself soon to be called a 'microbe', to the story told by Pasteur to the Academicians and to the reactions of Pasteur's interlocutors to his story.

Pasteur is engaged at once in *three* trials of strength that should be first *distinguished* and then *aligned* onto one another. First, in the story told by Pasteur there exist characters whose (semiotic) competence is defined by the performances they undergo. The 'hero', placed in front of a tricky choice between two different but deceptively intermixed outcomes, is at first puzzled and then, without hesitation, sorts out the two alternative branches, and triumphs, applauded by the elated audience. One can think of the story of Joan of Arc recognizing the King of France at Chinon in the middle of a crowd although He had disguised Himself and given His attire to another man but one can just as well think of the yeast able to select out, molecule after molecule, the right from the left handed version of the racemic acid that was designed to fool it. In both cases, the hero has undergone the difficult trial with success and defined part of its competence: 'she is really inspired'; 'it is really a living organism'. As far as stories go, 'Joan of Arc' and 'Clever Yeast' are comparable actors, although one is anthropomorphic and the other zoomorphic [See Figure 3].

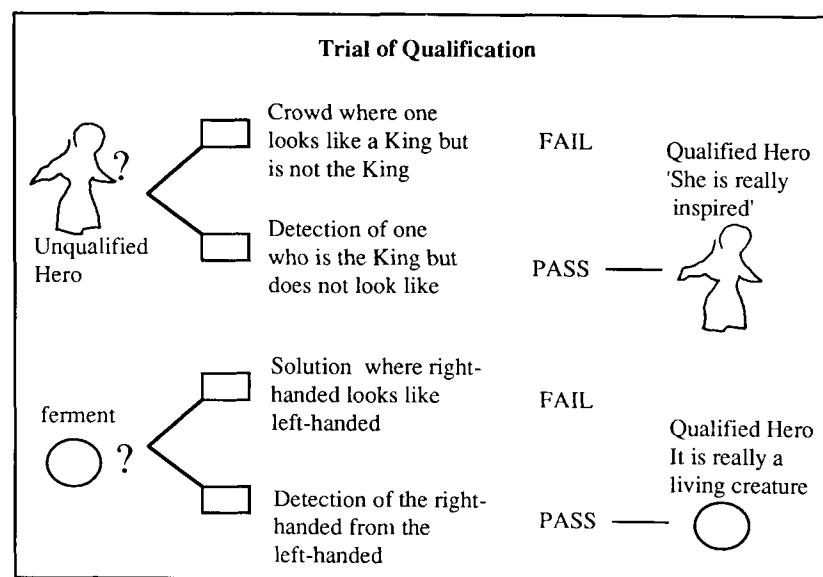


FIGURE 3

Second, Pasteur in his laboratory is busy staging a new artificial world in which to try out this new actor. He does not know what the essence of yeast is. In his laboratory he is a good pragmatist: essence is

existence and existence is action. How the hell does this actant behave in this medium (right-handed tartrate) and in that medium (racemic acid)? What does it produce (fermentation)? What does it break down? What it is up to? Most of an experimenter's ingenuity goes into devious plots and careful staging designed to make an actant participate in new and unexpected events that will then actively define it. He, Pasteur, had also been tried out by racemic acid a few years previously. An objection had been raised against his earlier work in crystallography. Pasteur triumphed by sorting out the left crystal from the right with tweezers under a microscope, thus showing that the racemic acid was a combination of the two forms in equal proportion. This was by now a non-problematic feature of his laboratory, know-how and equipment. Could the ferment be as clever as Pasteur's own hands and eyes? Could it have an activity similar to his? Why not? Pasteur invents a setting in which the yeast will be asked to do what Pasteur did: sort out the left-handed from the right-handed. The result of the experiment is to grant the would-be actor a sorting competence similar to that of Pasteur, only much quicker. Who is this little guy able to do in a moment what Pasteur has been doing at great cost?

The first trial is a story -- it pertains to language and is similar to any trial in fairy tales or mythologies. The second is a situation -- it pertains to non-verbal, non-linguistic components (glassware, yeasts, Pasteur, laboratory assistants). Or does it? The third trial is designed to answer this very question. Pasteur undergoes this new trial when he tells his story of the *Clever-Little-Yeast-Who-Can-Tell-Its-Right-From-Its-Left*. At the meeting on 29 March 1858, Pasteur is now trying to convince the Academicians that this story is not a story, but that it has occurred independently of his wishes and imaginative ability. To be sure, the laboratory setting is artificial and man-made but the competence of the yeast is *its* competence, in no way dependent on Pasteur's cleverness in inventing a trial that allows it to reveal itself. What happens if Pasteur wins this new (third) trial? A new competence will now be added to *his* definition. Pasteur is the one who has shown that yeast was a living organism; just as the second trial added a new competence to yeast: it can tell left from right. What happens if Pasteur fails? Well, the second trial has been wasted. Pasteur entertained his peers with the tale of *Clever Yeast* that was amusing to be sure, but which comprised his own expectations and earlier prowess [See Figure 4].

An experiment is, however, none of these three trials. It is the *movement* of the three *taken together when it succeeds or separated when it fails*. No experiment can be studied by being just in the laboratory, in

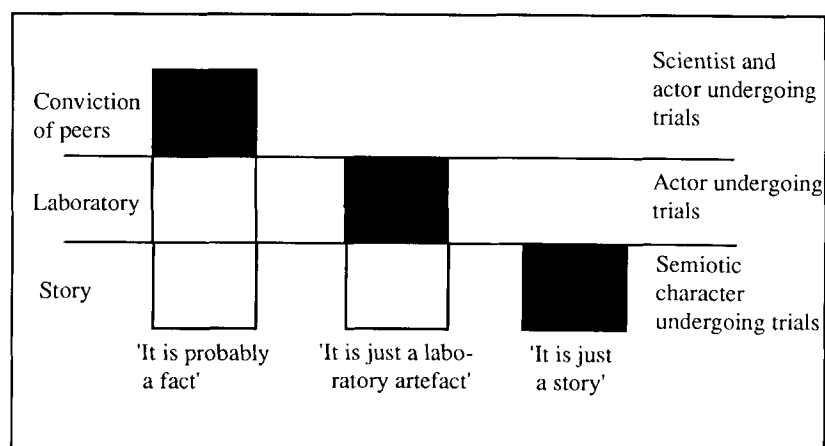


FIGURE 4

the literature or in the agonistic field. It is a story to be sure and studiable as such but a story *tied* to a situation where new actants are undergoing terrible trials plotted by an ingenious stage manager; and then, the stage manager is undergoing terrible trials at the hands of his colleagues who try out what sort of *ties* there are between the first story and the second situation. An experiment is a text about a non-textual situation tested by others to decide whether or not it is a text. If the final trial is successful then it *was not just a text*, there is indeed a real situation *behind* it, and both the actor and its authors are endowed with a common new competence: Pasteur has proven that the yeast is a living thing; the yeast is able to discriminate right from left. *They mutually exchange and enhance their properties*: Pasteur helps the microbe to show its mettle; the microbe, Pasteur to win one of his many medals. If the final trial be lost, then it *was just a text*, there is nothing behind to support it, and neither actor nor stage manager has won any *additional* competence. Their properties cancel each other out and colleagues can conclude that Pasteur has simply prompted the microbe to say what he wished it to. If Pasteur win we will find two (partially) new actors on the bottom line: a new yeast and a new Pasteur; if he lose, only one, he, the Pasteur of old, will be inscribed in the book together with a few shapeless and wasted chemicals. This triple definition of an experiment explains its two most prominent features as recognized by many analysts: first, it is both similar to literature yet wholly different; second, it is both artificial and real.

## 4. 'UN FAIT EST FAIT'

Scientific literature involves a very peculiar type of exegesis since it comprises a text that comments on another text -- as all exegesis does. But the latter is generated by way of situations and settings that are given the properties of inscribing, blotting, scratching, staining and writing. The passage between the three-dimensional setting and the narrative is obtained by the process of inscription. But, in addition to this first peculiarity, the text thus obtained is meant not only to be read. It is meant to fuel a polemic that tests the safety of this very passage from narrative to setting as provided by inscriptions. Moreover, once the polemic is closed, the result is no longer a text, but instruments, products, beliefs, know-how, equations, or other laboratories.<sup>7</sup> Pasteur's colleagues start making left acid tartrate. They do not just talk about it, they do not just write about it. From now on they work and live in a world where yeast is a living organism telling its right from its left, exactly as Pasteur learned to live in a world where racemic acid was made of the superimposed left and right crystals. Experiments do words with things and things with words through instruments, inscriptions and controversies. This is why scientists who obsessively inscribe, write and dispute, may say, with good grounds, that literature, inscriptions and controversies (the fodder of social studies of science) are of no relevance. This double-talk is no proof of scientists' false consciousness: depending on the outcome of the three trials defined above, texts, traces and polemics may indeed *lose* their relevance.<sup>8</sup>

The second main character of experiment is their artificiality that has been noticed by most analysts and most recently by Pinch (1986) Hacking (1983) and Knorr (1981). For Hacking, reference is interference or, as Bachelard sums up, 'un fait est fait' ['a fact is an artefact' or 'a fact is fabricated']. This is the case first because it is selected out of millions of other possible set-ups; second, because it is constructed in between instruments and is invisible as well as unthinkable without them ('phenomeno-technique'); third, because it is always underdetermined and has to be overdetermined by theoretical expectations. To whatever brand of realism a philosopher wishes to cling, the fabrication of phenomena in laboratories has to be accounted for. It is not even possible to overcome the problem by saying that artificial situations are there only to *reveal* or to dramatize the competences of phenomena which 'out there' would retain those properties quite independently from the artificial set-up. This 'out-thereness' has been shown to be always dependent on the *extension* of a laboratory situation which supposes, at



least in the beginning, the risky replication in another setting (Collins, 1985). There is no way to *demonstrate* that yeast selects the left acid tartrate without borrowing from a laboratory the polarimeter, the yeast culture, the know-how of crystallographers and microbiologists. Of course one can *believe* that yeast retains this property outside the laboratory but this is a belief, a respectable one, but not a demonstration. To be sure, the set-up may be simplified, routinized, black-boxed, so that it appears to spread effortlessly to many places but, if looked at carefully, the ties that hook up the black box to laboratories are always as visible as the cable that hooks a computer to the mains. No spread of laboratory artefacts will ever prove that the same (what could it mean?) phenomena (what could they be?) would be observed (by whom?) outside the laboratory (where that could be?). 'When a rationalist insists that behind the facts there is the *ground* of facts, the *possibility* of the facts, the tougher empiricists accuse him of taking the mere name and nature of a fact and clapping it behind the fact as a duplicate entity to make it possible' (James, 1907: 263)

All this is well known. It has been centuries now since a correspondence theory of truth has been articulated by anyone with the slightest acquaintance with the building of laboratories. And still, lo and behold, whatever we think or argue, the left acid tartrate is *not* invented by Pasteur, but by the yeast. At least, this is the very problem for his colleagues, for himself and for the little bug down in the crystal solution. It is essential to all of them that whatever the ingenuity of the experiment, whatever the perverse artificiality of the set-up, whatever the underdetermination or the weight of theoretical expectations, Pasteur manages to extract himself so as to become an 'experitus', that is, someone transformed by the manifestation of something not itself contrived by the former Pasteur. No matter how artificial the setting, something new, independent of the setting, has to get out, or else the whole enterprise is wasted. It is because of this 'dialectic' between fact and artefact, as Bachelard puts it, that although no philosopher defends a correspondence theory of truth it is absolutely impossible to be convinced by a constructivist argument for more than three minutes. Well, say an hour, to be fair. Most philosophy of science since Hume and Kant consists in dealing with, evading, hedging, coming back, recanting, solving, refuting, packing, unpacking this impossible antinomy: facts are experimentally made up and never escape from their man-made settings; it is essential that they are not made up and that something emerges which is *not* man-made. Bears in cages pace back and forth on their narrow turf with less obstinance and less distress than

philosophers and sociologists of science going from fact to artefact and back.

This obstinance and this distress are due to the definition of an experiment as a zero-sum game. If an experiment be a zero-sum game, if every output must be matched by an input, then nothing escapes from a laboratory that has not been put into it. Whatever the philosopher's list of the inputs in a setting, it always features the *same* elements before and after: the same Pasteur, the same yeast, the same colleagues, or the same theory. Unfortunately, since it is at once fabricated and not fabricated, there is always more in the experiment than was put in it. So, *explaining* the outcome of the experiment by using a list of stable factors and actors will always show a *deficit*. It is this very deficit that will then be accounted for differently by the various realist, constructivist, idealist, rationalist or dialectic persuasions. Each will *make up* the deficit by introducing their favourite stocks: Nature 'out there', macro- or micro-social factors, the transcendental Ego, theories, or the nice melting pot of dialecticians. There seems to be an endless supply of fat bank accounts upon which one can draw in order to complete the list and 'explain' away the originality of an experiment. In this kind of solution, the novelty is not accounted for by modifying the list of initial actors, but by adding one paramount factor that balances the account. In this way every input is equilibrated by an output. Nothing new has happened. Nature (or society, or theory, or *x*) has simply been *revealed* at the occasion of an experiment.

But, nothing proves that an experiment is a zero-sum game. On the contrary, every difficulty above suggests that *an experiment is an event*. No event can be accounted for by listing the elements that enter the situation *before* Pasteur launched his experiment, *before* the yeast started to eat up the right handed tartrate, *before* the meeting of the Academy. If such a list were made, the actors would *not* be endowed with the competence that they will *acquire* in the event: Pasteur is a promising crystallographer but he has not shown to anyone's satisfaction that the ferments were living creatures; the yeast may accompany the fermentation, as Liebig claimed, but is not yet endowed with the property of selecting out left- from right-handed crystals; as for Academicians they do not depend on a living yeast in their own laboratories but prefer to remain on the solid ground of chemistry. The list of inputs does not have to be completed by drawing upon any stock resource, since the one drawn upon *before* the experimental event is not the same as the one drawn upon *after*. This is precisely why an experiment is an event and not a discovery, an uncovering, an

imposition, a synthetic *a priori* judgement, the actualization of a potentiality, and so on. This is also why the list drawn after the experiment shows no deficit whatsoever: a (partially) new Pasteur, a (partially) new yeast and a (partially) new Academy, are all congratulating each other. In the words of Isabelle Stengers, an experiment should not be explained by 'the principle of sufficient reason'.<sup>9</sup> The reasons brought to bear on the explanation are insufficient, not because one factor has been forgotten, or because the list has not been carefully drawn, but because actors *gain* their definition through the very trials of the experiment. It is always admitted that science grows through experiment: the point is that Pasteur is also modified and grows through this experiment, as does the Academy, and, yes, as does the yeast. They *all* leave their meeting in a different state than which they went into. In other words, there is a history of science, not only of scientists and there is a history of things, not only of science.<sup>10</sup>

This proposition itself has to be put to the test. There is no better example than the Tasmanian coast, chosen above as a paradoxical case of experiment. If it can be shown that such an obvious counterexample is a collective and continuous historical event then *a fortiori* it will be the case for facts/artefacts that are clearly laboratory-made. In what sense is Baudin's voyage an event that should not be accounted for simply by a list of stable actors? There is no difficulty in realizing how deeply the voyage is an event for Baudin since he dies in the process. It is also an event, although a lesser one than which was expected, for the commissioners of his expedition back in Paris; their maps of the Southern Hemisphere will never be exactly the same afterwards. But in what sense is Tasmania *herself* an actor modified in the trial?<sup>11</sup> That Tasmanians will never be the same afterward is clear from the elder's perceptive appraisal of the dynamometer; they are all doomed. That the landscape will be deeply and lastingly modified, is also clear, terribly clear to anyone now driving through the Verdun-like landscape of deforested land. But what about the coast, the land mass, the shape of the land, in what sense can these be said to be partially constructed and partially realized during the experimental event of Baudin's mission?

First of all, a coastline is also an actor in the definition given above; *i.e.*, it does things. For instance, it has the nasty custom of wrecking ships, of hiding itself in mist and rains. It is also unpredictable, as much as a cloud shape. From the shape of this cape no one on earth could deduce that there will be a bay, an island or a river estuary behind except, that is, the *second* navigator who reads the map drawn by the first and 'deduces' from the characteristic recorded shape of 'Presqu'île

du Nord' that, for sure, the 'Riviere du Nord' lies behind. To establish the first map and make the life of the second navigator easier, certain coded details of the coast have to be gently experimented on by a ship coming close -- not too close; staying away -- not too far; moving gently -- not too slowly, not too fast; and taking bearings that have to be carefully recorded, summed and projected. The coastline and the landmass are laboratory events; they are unpredictable at first and then slowly and painstakingly stabilized. To hold this cape down there in the mist, to make it out as a characteristic shape, to introduce it in the sequence of movement that leads you to the 'Riviere du Nord', you need to enter it, like any other object, as a written answer to a succession of trials (what longitude? what latitude? what height? which profile when approached from the east?).

Is it possible to jump *out* of the experiment being made by the ship to the Tasmania out there? No, because to tell *what* is out there or even whether this is Tasmania or not, you have to rely on just this laboratory work. Baudin happens to this cape as much as the cape happens to Baudin (Law: 1986). It is given a name, it is recorded, extracted, characterized, stabilized, sequenced. No one could say that it was there before Baudin, without pointing at or thumping on another, earlier map, and since it is Baudin who made the first map, this would be difficult! The only way to argue that it was there before and independently of Baudin and of the Dutch and English cartographers would be to point at a *shapeless* mass of land that would *not* take into account any of the details experimented on by those expeditions. Thus, going back in the past, undoing what each navigator has done, erasing the result of each map in turn, the obstinate realist will be left pointing at a shape that has become so shapeless that it will not be called Tasmania any more but Terra Australis Incognita, of which nothing can be said. In the end, he or she will be left pointing an index finger at 'It There'. Either you fill the reference 'It There' with something specific and you have to get nearer the collective work of cartographers and administrators and colonizers, or you stay away from this work and are left with a reference to nothing in particular. You can't have your reference and eat it too.<sup>12</sup>

This impossibility of escaping from collective work does not mean that Baudin invented Tasmania out of his head. Or, at least, this nagging doubt is slowly being rejected by the many actors who raise for themselves this very philosophical question: is Baudin reliable? How real is his map? Less and less can people argue that Tasmania was invented by Baudin, since in Paris, in London and at Botany Bay, different maps are compared, superimposed, and create an *internal referent* that settles

the discussion: Baudin has not made it up. Other navigators are adding to his definition. Tasmania's coastline starts to stabilize there in the cartographers' cabinets and in the colonial offices by calibrating the laboratories (Jardine: 1986). Whereas it had been texts and reports, actions and hardship, heated discussions, it is now a black box. The result of the experiment is now sunk deeper in other types of practice, instrument, deduction, and cliché. From now on, they all learn to live in a world to which is added a Tasmania of *that* shape [See Figure 5].

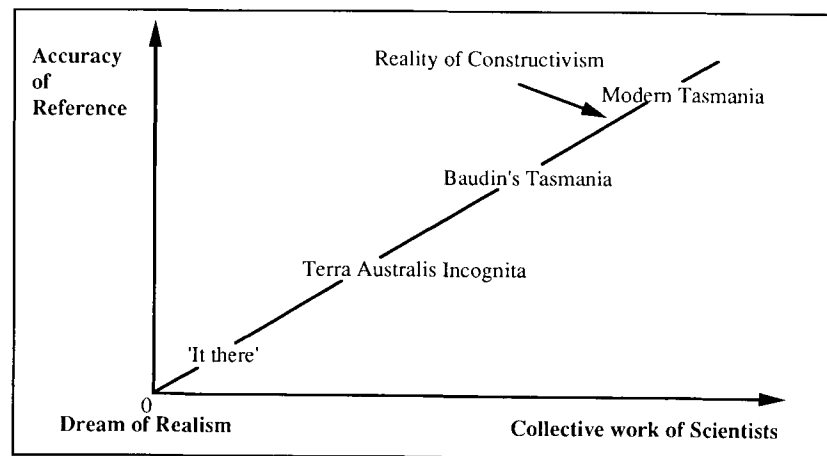


FIGURE 5

But, what about Tasmania herself? She is no longer herself, that is the point. Like the sleeping Gulliver she is now tied solidly by a great number of tiny but tight links fastened by those Lilliputians. She can't move and disappear. More and more frequently fleets are coming to her shores. For her coastline to become stable and reliable, for the map of Tasmania to look like Tasmania, capes are equipped with signals and light houses, towns are marked by names and signs, so that now more and more people sailing 'there' may establish a 'correspondence' between the map and the coast. The laboratory situation of the cartographer is now brought back to the place to which it 'refers'. Words like 'correspondence' and 'reference' are not mysterious and forbidden terms. They do not designate the useless *extremes* of Reality and Representation, but the collective work *in the middle* which builds reversible translations between inscriptions on the scaled-down map and scale one Tasmania (see Brannigan, 1981 on Columbus' work). They

now designate the *extension* of laboratory conditions to stabilize the actors' definition and to render it *durable*. It is this passage from words to things and from things to words that is so difficult to follow for those who oppose Nature and Signs or Reference and Interference. The two extremes (Representation and Reality) are not the most important parts of this network of actions and events and no one has ever to account for the face-to-face meeting of these two equally shadowy figures. The whole reality-representation is spread in the middle and along this network no one in particular is more important than any other. They all compose this on-going event: Tasmania. And, this event is not yet achieved. You, too, happen to Tasmania as much as she happens to you.

If I go to Tasmania in order to solve this question, I realize indeed that the Tasmania where I am standing now is *not* on the map of Tasmania. This eucalyptus half hidden in the mist, this flying wild goose, this creek, this fern, this destruction are not inscribed on it. When I am out there it is not on the map and when I read the map the place where I stand is not there. To be sure, there are connections in certain crucial points between names on my map and names that I come across: 'Devonport' is on the map and I also see a sign 'Devonport 1 km'; the distances in kilometres between Devonport and Hobart are the same on these signs as they are on the map. I can superimpose these two readings and they will more or less fit with one another. But this correspondence does not count as one between Representation and Reality since they are both coming from the same source -- cartography, administration, surveying -- and since the signals and posts have been fixed in the ground to turn a few landmarks into annexes and complements of the map. If you destroy the signals and ask me to test the relation between my map and this extent of land, I will start to be lost. I may ask someone 'Is this Devonport?' But, now let us take out, one after one, each inhabitant whose collective experience grounds the map and its landmarks solidly into Tasmania. What happens to me when I land 'there', with no one to ask 'where' is Devonport or whether indeed this is Tasmania or Australia or King Island? I have to become a geographer, a cartographer, and explorer. So I have to do the work of mapping all over again. My present weight is little compared to that of the island? But, this is because I am a tourist coming after two hundred years of visits, actions on and exactions from Tasmania. Although a visit to her shore transforms me more than it transforms her I still happen to her, a little bit; I am a Lilliputian part of her construction.<sup>13</sup> She is the reference provided you add to her definition the work of all of those who ground her, and the instruments and embodiment of all of those

who are still acting to make her exist and survive. This continuous and collective historicity of *all* actors when they enter into a new trial solves the antinomy of fact and artefact -- they are made up; they are not made up.

The question raised by realism (does this acid or this coast correspond to something out there?) may now be separated in its two *components*: a true passion and a wrong solution [See Figure 6]. There

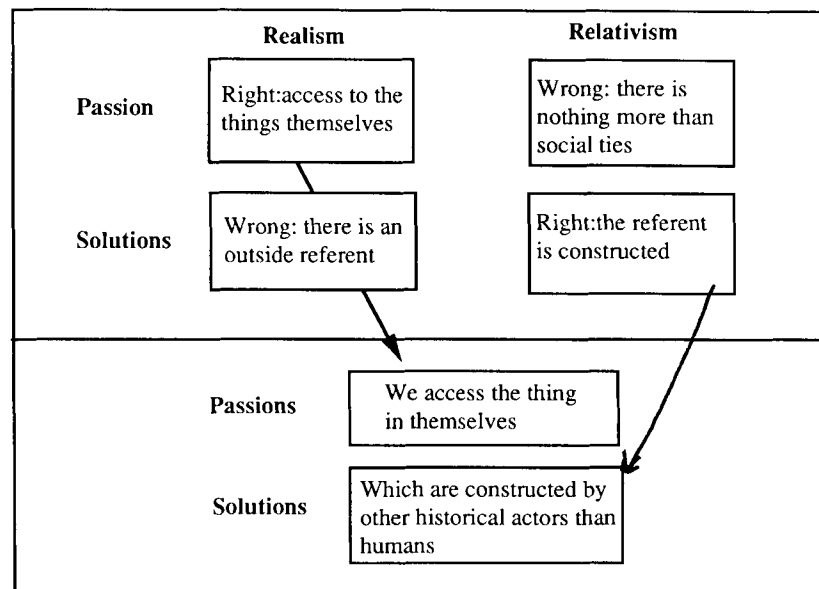


FIGURE 6

is among realists a passion for accessing the things themselves, for building the world with more than social ties, with more than human minds and this passion should be retained. The wrong solution to fulfil this passion is to claim a fanciful repetitive projection of what the sciences do into what the world is, and that solution should be ruthlessly discarded (Woolgar: 1988).<sup>14</sup> The same distinction may be brought to bear upon the various brands of constructivism: it is a practical and pragmatic solution to a wrong passion; laboratory settings and experiments are indeed historical and local achievements; but the passion to reduce them to a *stable* list of theoretical, cognitive, or social human factors is unnecessary. More precisely, the polemic passion of constructivists is triggered, understandably, by the absurd solution of

realists, and this solution in turn is seen, quite understandably, as the only way to escape the constructivists' solution; hence the Tom and Jerry type of chase in which they all so much delight. But, there is a way out which consists in choosing the pragmatic solution to express the right sort of passion: *a little bit of constructivism takes you far away from realism; a complete constructivism brings you back to it*, even though the population of actors having a common history will never resemble the old Out-Thereness. Thus constructivism is not to be confused with construction by society. In building our world we (man? mind? society? ideas? labour? episteme?) are far from being the only actors. You can have your cake and eat it too, or, to remain amidst gastronomic metaphors, there is such a thing as a free lunch.

### 5. PRAGMATOGONY

The most striking feature of the consultations that we are going to study is the following: when the *kindani* [diviner] 'works' for the preparation of public ceremonies he puts himself in the hands of the king who is mainly responsible to the society for the fortune or misfortune bestowed by the invisible powers that govern human destiny.... This is why the consultations are made on a grand scale. They may last one, two or three weeks.... They are held under the direct control of the King of Lere who is constantly informed of the partial results and of the problems encountered. If, for instance, sacrifices are necessary to modify a statement which is especially worrying, the King provides the animal (chicken, goat or sheep) whose blood will be spread where the draws are made, after which the meat is eaten by the diviners.... When the *kindani* is completed, the King comes to the consultation arena to have the results read and commented. He then offers gifts to the *pa-kindani*: mil, tobacco, beer, silver.

Having the shape of a large imperfect circle of around thirty meters in radius, the *tehale* [sacred enclosure] is a depression surrounded by *tebakame* (balanites aegyptiaca). Inside this circle are also planted a few of these trees at the foot of which are seated the diviners to work with their stones or more exactly with the special stones that never leave this *tehale*. Big river pebbles which are amassed around will be used to report the final results on the outside circles. At the end of the *kindani*, these results will be recapitulated and discussed in front of the King and his retinue who will then have, if there are two rows of stones inscribed on the soil, almost four hundred meters of 'sooth-saying text' to inspect (Adler & Zempeni, 1972: 153).

Here is another King, not Hiero of Syracuse but the King of Lere in Chad. Here are other specialists, the *pa-kindani*, who *work* in an *insulated* enclosure with *specialized* tools (stones and pebbles which are thrown at random), wasting laboratory animals in the process (not rabbits and rats, but chickens and goats). Here is an *inscription device* of great proportions where each result is carefully recapitulated into rows

of other stones, the disposition of which are endowed with technical meaning. Here is another public *experiment*.

It will be remembered how Plutarch cleansed Archimedes of all attachments to this base world of mechanics after he had impressed the public and defended Syracuse. Here too there is a rite of erasure. In the final day of the *kindani*, the King's horsemen race to the consultation arena and dismantle the sacred writings with the hooves of their horses, while the diviners wash themselves and cast a spell on the horses' hooves, passing to them the responsibility for the spells that were inscribed in the stones: 'we are not the cause of the misfortunes here inscribed' they say. Whereafter the horsemen rush to the river and cleanse their mounts of any accusation. Nothing has happened. The arena is neutral again. This being the end of the public experiment, the new year ceremonies may begin (185-6).

Syracuse, no doubt, was full of such experiments at the time of Archimedes' trial; so was Tasmania before the aborigines had to submit to Peron's silly dynamometer; so might have been the city of Strasbourg while Pasteur was busy teaching tricks to his yeast. All of them, scientific or prescientific, have the common feature that they are man-made and yet still introduce into our commerce elements that do not depend on our will and human intention. It was the mathematical world of demonstrations that Archimedes was bringing to bear upon the usual political affairs; as for Baudin or Pasteur, their colleagues became convinced that they had not made up their whole stories; that they were indeed bringing into our world a new bit of Tasmanian coast and a new actor, the living yeast; and that these were here to stay with us as part of our world. The *pa-kindani* also insist that they are *not the ones doing* the inscriptions. It is at random that they throw their stones. They do not bias the throw. They do not cheat. It is at the occasion of this non-human, non-social, non-political draw that the powers that govern our destiny indicate what they want us to do. The diviners are as surprised by the results, as worried by them, as the public might be. As any good scientist would do, they ask the King for new sacrificial animals in order to *replicate* the surprising statement and to check whether or not they can withstand another test. The data are so independent of their will that they wash and decontaminate themselves, in the end taking no responsibility for the inscriptions, but instead throwing them to the horses.

Could their honesty be doubted? Yes, but Plutarch's, Peron's or Pasteur's experimental or story-telling abilities could also be contested. Maybe the *pa-kindani* skew the throws of the stones to manipulate the

King or the clans? Surely, but Archimedes manipulates Hiero as effectively as the trireme; Peron's critique of the Noble Savage is highly distorted; as for Pasteur, he will soon move the whole of France with his microbes. So what is the difference, if any? To pin-point this difference, it might not be necessary to doubt the Moudang's honesty, or to invent some form of 'savage mind', or belief in witchcraft, or to redefine any deep Great Divide.<sup>15</sup> Even if all our characters, scientific and pre-scientific, are assumed to be honest experimenters in contact with non-human actors which are not their invention, a difference remains:

The primary function of the *kindani* is a complete inscription answering a complete demand of the society.... During the *kindani*, after having checked whether or not the supernatural powers, the village and its land, are in favourable dispositions, the question is to spot and control people.... The *kindani* is simply an enumeration of all the characters who, for one reason or another, are part of the representation of the ceremony... The control of people in the preparation of the collective ceremony aims at verifying their ritual capacity: are they in the required state of purity and integrity so that, because of them, the community is not put in any danger now that it has entered a ritual period? (183-4)

The *kindani* is presented -- in as much as we can believe Adler and Zempeni's report more than Peron's statistics! -- as a huge *checklist* of all the relevant aspects of the society, before another year begins. Each notable, each village, each clan, each of the king's wives, granary and organs, each of the government executives, is inspected one after the other with a throw of stones and required to do something if the answer is dubious or threatening -- amend or sacrifice. The divination, the stones, the rites, the independence of the diviners, are employed to underline, mark, test and repair the ties of the social fabric, very much as a fisherman would do with each mesh of his net before setting sail. Is the social structure disguised by the rite? Are the diviners really using their knowledge of their society under the pretence of non-human throws of chance? Is their independence a mockery? No, because the social structure is in part made by this check list, repair work, and close annual inspection, just as the fisherman's net, after years of inspection and repair, ends up being a new net. There is no difference between building and repairing. The non-human stones, the independent diviners, and the transcendental power that talks through chance, are necessary components of the society. No society of humans exists without the non-humans to hold it together.

So what is the difference between Archimedes on the beach and the Moudang in the middle of their stones? What is the difference between what we call an experiment, a scientific one, and what we, academic

Westerners, no longer call experiment? After all, in both cases there exists a genuine appeal to non-humans and a true independence of the experimenters overwhelmed by realities they do not control, even though each have a clever hand in fabricating them? The answer is to be found in the *movement* of the non-humans and in the *direction* their spokesmen impose on them as a way of reinforcing *or modifying* the fabric of social links.

A 'thing', etymologically, is an assembly, usually a judiciary assembly in the course of which an accusation is made: the root is the same in Latin, 'causa' and French, 'chose' (Serres, 1987). Thus, the first origin of a thing is a collective assembled to accuse and probably to sacrifice. Serres calls 'pragmatogony' the slow movement that leads through a series of substitutions from a purely social and collective definition of the 'thing' to a definition that requires more and more 'objects' to hold it together. You start with a collective; you end with a collective *plus* a nature, *plus* technique. You start with a judiciary cause; you end with a scientific cause. You start with an accusation; you end with a causation.

At each step of the (necessarily mythical) pragmatogony, non-humans are mobilized, enrolled, lifted out of their environment, to be brought to bear on social links, but their movement, their aim, their 'angular velocity', so to speak, is not the same. In the *kindani*, for instance, the non-humans are used by the diviners to trace, or retrace the already established but constantly weakening social ties: family lines, clans, land tenures, purification rites, power structure. These ties would not be visible without the passage of these 'tracers'. The tracers play the same role as the ball in a game of rugby. The ball seems to be what the game is about, since everyone tries to reach it, but as soon as one holds it, it is got rid of and passed to someone else. In the end, it is the trajectories of the successive *passes* that define, *in actu*, the collective. Similarly, the stones thrown at random are cleverly directed by the diviners to each of the relevant points of the society that is completely mapped out in three weeks and inscribed in rows of stones. Of course, the diviners are not doing a directly social analysis, but anyway such a 'directly social analysis' is the Western anthropologist's understanding of the whole rite. For the Moudang, the randomness of the stones, the mediation of the diviners, the invocation to supernatural powers are necessary elements of the analysis just as the ball being sought and shifted is a necessary component of the game of rugby. Could teams 'directly' run against one another and bump into each other and fight without a ball? Could diviners 'simply' tell who is powerful and who is

not, who is sick and who is dangerous? No. The non-humans (balls, rules, stones, gods) are necessary for the collective to exist. But, since these non-humans are neither objects nor subjects, natural or social, Serres calls them '*quasi-objects*'. Are they here simply to trace, reveal, mediate, reinforce the whole collective? No, they are there to turn the scattered assembly into a whole, to repair the decaying collective. They are there to collect the assembly, to perform the society. This is why their *trajectory* is essential. It is crucial that they be both non-humans and completely collective, able to trace all the details of the collective without forgetting any member or articulation. If they stop, they lose meaning. If they be human, too human, they lose meaning. Are the diviners of the *kindani* cheating? Certainly yes, they have to, but it does not matter. In three weeks the whole society has been mapped out, inspected, checked up, repaired, reconciled, ready for another go.<sup>16</sup> Who did this? No human did it. The hooves of the horses have erased everything and have then been cleansed of the spell.

Archimedes' lever, Peron's statistics, Baudin's coastline, Pasteur's yeast, circulate very differently through the collective. They too are non-human. They too are man-made. They too are brought to bear on the collective. But what do they do, once brought in the collective? *Locally* they *create a unanimity* and, once this unanimity is ensured, they *reverse the relations of forces* elsewhere in the society. Their mode of circulation does not turn them into quasi-objects. We are now much further into the (mythical) pragmatogony. They have become *objects*, things, black boxes no one has made and which are going to change everyone's world. The quasi-objects were living in our social world. We are going to live in a natural or technical world of objects. There was one world, *made* one by the circulation of quasi-objects. There will be many worlds spread apart by the circulation of objects.

Much has been made of the ability of experiments to put otiose discussions to an end. 'Settle matters of fact first, and useless chats, polemics and verbosity will be stopped', thus speaks the scientific wisdom. But, this interruption of debates is carefully circumscribed as it has been so beautifully shown by Shapin and Schaffer (1985) in the case of Boyle's experiments. To be sure, discussions about the validity of Archimedes' demonstration are no longer possible among the King's retinue; debates about the strength of Primitive Man die out in the meetings of the Paris Societe des Observateurs de l'Homme; opposition to the idea of living yeasts peters out under the Academy cupola. But, what about the rest of the social fabric? What about the complement of this set? It is transformed, disrupted, destroyed, reshaped, by the

quasi-miraculous intervention of non-humans accompanied by their spokesmen. The age-old relations of force are reversed by Archimedes' pulleys; the Tasmanians are wiped out; convicts are moved to another hemisphere; breweries are transformed by microbiology. The paradox of experimentation is that the locally achieved consensus is paid for elsewhere by a refuelling of dissensus on a new and larger scale. The grey boxes of the *kindani* could not reach further than the very society it mapped out. The black boxes of the experimenters allow action at a distance. It is because the controversies are locally settled by matters-of-fact, that the rest of society may be moved out of its usual ways. Indeed, the very relation between the few settings where matters-of-fact are settled and the rest of society reproduces the very shape of the lever.<sup>17</sup> A little weight moves a great one: 'Give me a laboratory and I will raise the world'.

Do not try to raise the world with quasi-objects; you will not have the leverage and you *will not have another social world from which to modify the first*. You can do whatever you want with quasi-objects, but there is one thing you cannot do and that is to reverse the relations of forces in any grand way. You can alter, modify, repair the social ties, but not make a gaping hole in them and replace them by non-humans. Convinced collectives of experimenters, however, will do just that. Quasi-objects have to be able to circulate everywhere to trace social ties. It is enough for objects to stop inside the laboratory walls. In order to circulate everywhere quasi-objects have to be continuously open to compromises, interpretations, negotiations. Objects, when they are pushed out of the laboratory settings, have to be uncontroversible black boxes which no one can renegotiate. It does not matter too much if there be a doubt on the origin of quasi-objects; are they really coming from the gods, the diviners, the King? A large uncertainty is not only possible, but is necessary to allow the tracing of the social fabric. But it matters enormously, obsessively, uniquely, whether laboratory objects are man-made or not. The whole point -- the Archimedean point! -- is missing if it can be proved that the scientists have only other humans (interest, politics, affectivity, psychology) behind them rather than the non-humans they claim to reveal.

The peculiar anthropological trait of scientists is that they have to insist on the absolute distinction between non-humans and humans, and that, nevertheless, this locally achieved absolute distinction is immediately transformed into a modification (slight or deep) of our world. Like Archimedes, they establish a continuity, a commensurability, a law of proportion between reason and force, and then sever all

thinkable links between force and reason. Truth is not an obsession of the *pa-kindani*; the circulation of quasi-objects through the society is, and so too is the turning of the society into *one single* society. But it can be safely concluded that truth is the obsession of the experimenter, as is the circulation of *objects* through one society that it turns into several.

Both types of societies resist the ethnographer's account of their similarities and differences with the same zeal. Other societies are furious when the rationalist Western ethnographer tells them that they need to distinguish between knowledge and society, between their culturally biased *view* of the world and what the world *really* is. We, in turn, are furious when the ethnographer of science, equipped with the tools and methods of the exotic fields, insists that we should make no distinction between our knowledge and our society, between what the world really is and the highly cultural ways in which we shape it. The first ethnographer imposes a *dualism* that threatens the society he studies; the second ethnographer imposes a *monism* that threatens the society in which he lives. These two impositions and these two flares of anger and passion are probably unnecessary. The clever anthropologist (who has first moved to study other cultures, then has come back to study ours, and who then ponders why so much passion is generated by these two types of explanations) realizes that the two might be equally misleading. He now sits in the middle of the Great Divide and learns that what defines one society cannot be used to define others: instead we have to see *our* dualism between science and society and *their* monism as the two major features of the two types of societies. The ethnographer of science who sits over the Great Divide is not confronted with prescientific and scientific worlds, but with societies which would fall apart if a distinction were made between their knowledge and their social fabric, between reason and force, and others, that is our society, which would fall apart if this distinction were *not* made.

#### ACKNOWLEDGEMENTS

I thank the History and Philosophy of Science Department of the University of Melbourne for the two month leave that made this paper possible. I thank Isabelle Stengers for her passionate understanding of realism. My friend Steve Woolgar who kindly corrected the English wrote 'I am not the cause of the misfortunes here inscribed'.



## NOTES

1. This experiment is still the most popular and the most often staged in 'hands on' science museums. It offers little kids the nice occasion of reversing the balance of forces by dragging effortlessly their father, thus learning the easy way in what the social studies of science consists and why the accusation so often made against 'constructivists' and 'relativists' of relishing 'mere relations of strength' is so misleading. See Authier (1989).
2. As usual, the critiques of the 'constructivists' attribute this obsession for relations of forces to us when we are simply trying to give the philosophical framework (Latour, 1988: Part II) that render understandable the scientists' obsession for establishing and then denying relations of forces. Killing the messenger is the strategy of those people who strangely enough accuse us of immorality!
3. 'Description et usage du Dynamometre' par le C.<sup>en</sup> Regnier. On Regnier and Peron see the detailed studies by Miranda Hughes (1988a; 1988b; this volume)
4. At least if the statistical challenge is not too strong since Peron manages to capture only 18 readings for the whole Southern Hemisphere.
5. They meet and combine with other paper forms which are visually, optically, and geometrically compatible (coming from thought experiments, from theoretical calculations, or from numeric simulations) in such a way that to do the work in the centre the origin of the various written sources becomes irrelevant except in case of doubt or controversy (see Latour, 1987: Ch. VI).
6. *Comptes rendus de l'Academie des Sciences*, seance du 29 mars 1858, XLVI: 615-8).
7. For all this movement see Latour (1987) and Callon, Law & Rip (1986).
8. This is enough to see the main difference with fiction. In the 'high' literature, a text is not about another one present in it under the form of inscriptions (internal/external referents); it cannot be summarized and never loses its relevance *qua* text (you cannot replace Proust's *Recherche* by an abstract without losing the *Recherche* but summarizing a long article is what it is made for); it is not normally inserted in a controversy among people who are the author's peers so as to test the ties between the narrative and the referent to which they subscribe. This huge difference in the regime of *enunciation* does not mean that scientific texts cannot be studied with the normal tools of text semiotics. As far as the *enunciate* is concerned, they are fully comparable. See Bastide (in preparation).
9. The principle of sufficient reason defined by Leibniz states that there is nothing in the cause that is not in the effect and *vice versa*. The two lists balance so exactly that the phenomenon under scrutiny may be made *reversible*: the effects may give the cause back. This is both the principle of determinism and the dream of scientific reason: give me the conditions, all the conditions, I will give you the effect, all the effect, and *vice versa*. But Prigogine and Stengers (1988) argue that this principle does not work better for physics, cosmology or chemistry than for the 'narrative sciences'. Irreversible events are not defined by their conditions of possibility.
10. The limit of pragmatism is to be concentrated on man (individual at that). But if essence is existence and existence is action, this pragmatism is to be extended to the things in themselves now endowed with a history. James was ready to 'add to reality'. He transforms the metaphor of the Book of Nature, from a book one reads to a book one writes ('on the pragmatist side we have only one edition of the universe, unfinished, growing in all sorts of places, especially in the places where thinking beings are at work. On the rationalist side we have a universe in many editions, one real one, the infinite folio, or *edition de luxe*, eternally complete; and then the various finite editions, full of

- false readings, distorted and mutilated each in its own ways' (1907: 259). But, he was prepared to do it as you add shape to a shapeless and plastic matter, not as you meet other non-human actors who have also their history. This shift away from human overcomes the other limit of pragmatists. They are unable to explain the *enduring* quality of a settled dispute. They have no way slowly to withdraw existence out of essence. This withdrawal occurs by shifting the task of maintaining the consensus to non-humans and moving from interactions, talks and controversial practices to a world *in which* we live.
11. It would be all too easy to talk of plate tectonics so as to add activity to the shape and position of Tasmania but I would have to rely on another discipline: geophysics. I am trying here the hard case of 'purely descriptive' cartography.
  12. This is why realists are never able to *deliver* the Reality their feeling for reality is seeking; paradoxically, this Reality will be provided by Constructivists who like to describe themselves as having no special craving for Reality (see below). It is because we like reality so much that we have all been engaged in the detailed description of the nitty-gritty of science in the making.
  13. So much for the classic distinction between what is socially new and what is personally new, between the discovery of things no other human has found and what is learned by students and tourists. The learning of an age-old discovery is part and parcel of this very discovery even if the weight of the new discoverer is comparatively small.
  14. The belief in a correspondence theory is easily explained, however, when one considers the *superimposition* of traces and inscriptions on which scientists rely to build a proof. It is perfectly accurate to say that we have no other way of proving than by subscription, that is, by underwriting one layer of documents by another one. This process, however, remains inside the laboratory. It builds the *internal* referent, not the external one. It is the mistake of the correspondence theory to take a genuine process inside experimental practice for the external cause of its solidity.
  15. On this question of the Great Divide see Horton (1977; 1982). In his first article he distinguishes between open and closed predicaments in order to account for the difference between Us and They. Then, in his second article he rephrases his argument using primary theories (which are universal) and secondary theories (which are elaborated in our societies by rival schools and disciplines). The major point is that They try to maintain at all costs one 'single overarching frame' whereas We don't.
  16. This is the limitation of Horton's excellent analysis of his Little Divide: he provides no mechanism for the 'one single overarching framework' to be *made* one, *made* overarching and *made* a frame. To do so one has to introduce the trajectory of quasi-objects, a mapping mechanism of some sort in order to perform and maintain the unity of the frame. Goody (1977) offers a much more tractable solution since he focuses on intellectual technologies.
  17. Mary Hesse insists on the difference between metaphoric and metonymic relations to express the same distinction as the one between quasi-objects and objects. To take the part for the whole is, she says, the scientists' obsession. The part (scale model, laboratory, theory, maps, models, experimental fields) is the whole. In other terms, if instead of quasi-objects, immutable mobiles are made to circulate a different society is traced out and performed.

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*Ecole des Mines, Paris*

## THE DYNAMOMETER AND THE DIEMENESE

I am the first to have opposed actual experiments and numerous facts to an opinion which is too prevalent, perhaps too dangerous and certainly too exclusive, that the physical degeneration of man follows the improvement of civilization.

With these words Francois Auguste Peron (1807) set his experimental results against the conventional beliefs of the eighteenth century. His 'actual experiments' involved the use of a dynamometer to measure loin and hand strength. The dynamometer became the lever to overturn the cherished Enlightenment doctrine of the Noble Savage. Rejecting the long-held assumption of a natural relationship between savagery and strength, Peron claims instead that the state of savagery is inherently a state of feebleness.

Labillardiere and Coulomb's (1804) report on Peron's 'Experiences sur la force physique des peuples sauvages de la Terre de Diemen, de la Nouvelle Hollande et des habitants de Timor' recommended publication in the Institut de France's *Memoires des Savans Etrangers*. This endorsement from the most prestigious scientific body in Europe indicates that Peron's experiments in anthropology well fitted the accepted scientific methodology and that no distinction was then perceived between experiments in physics and chemistry and those in the human sciences. Peron, through his application of the practices of experimental natural philosophy (see Schuster & Watchirs, this volume), sided with that discipline's concept of objectification through the use of data against the traditional approaches of Enlightenment 'anthropology' in which *philosophes* rarely ventured beyond the armchairs in a salon.<sup>1</sup>

### 1. THE PORTABLE DYNAMOMETER

The dynamometer measures the amount of muscular force exerted by a human or animal. The portable dynamometer was developed by the physicist Edmund Regnier in 1798 in response to a request from Buffon who suggested the need for a device that could be used in a wide variety of situations and would be less cumbersome than the available English

AUSTRALASIAN STUDIES  
IN HISTORY AND PHILOSOPHY OF SCIENCE

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KLUWER ACADEMIC PUBLISHERS

DORDRECHT / BOSTON / LONDON

Library of Congress Cataloging in Publication Data

Experimental inquiries : historical, philosophical and social studies  
of experimentation in science / edited by Homer Le Grand.

p. cm. -- (Australasian studies in history and philosophy of  
science ; v. 18)

Includes bibliographical references and index.

ISBN (invalid) 07923070909 (alk. paper)

1. Science--Experiments--History. 2. Science--Experiments--  
Philosophy. 3. Science--Experiments--Social aspects. I. LeGrand,  
H.E. (Homer Eugene), 1944- II. Series.

Q182.3.E96 1990

507.2--dc20

90-4571

ISBN 0-7923-0790-9

Published by Kluwer Academic Publishers,  
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Kluwer Academic Publishers incorporates  
the publishing programmes of  
D. Reidel, Martinus Nijhoff, Dr W. Junk and MTP Press.

Sold and distributed in the U.S.A. and Canada  
by Kluwer Academic Publishers,  
101 Philip Drive, Norwell, MA 02061, U.S.A.

In all other countries, sold and distributed  
by Kluwer Academic Publishers Group,  
P.O. Box 322, 3300 AH Dordrecht, The Netherlands.

*Printed on acid-free paper*

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Printed in the Netherlands

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