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Leviathan and the Air-Pump
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Leviathan and the Air Pump:
A Historical Study of the Emergence of the Laboratory Style and the Creation of Phenomena

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Abstract:
Leviathan and the Air Pump represents, for Hacking, a story of unparalleled value for illustrating and working on several of his fundamental projects. It is the story of the historical conditions of possibility that allowed, in the 17th century, the emergence of the laboratory style of thinking & doing, based on the creation of a device in the experimental cabinet -the pump- with which to intervene in the world and create a new phenomenon -the void. Just as *The Emergence of Probability* and *The Taming of Chance* constitute not only examples of the application of scientific styles, but also the historical background that inspires this Hackinian notion, in Shapin y Schaffer's book, Hacking finds the historical background for the new style he proposes: the laboratory style. This paper begins by presenting Hacking's proposed styles of scientific thinking & doing, then focuses on his characterization of the laboratory style. It concludes with an analysis of Hacking's use of the history of Hobbes, Boyle, and the vacuum pump to illustrate his aforementioned projects.

Keywords: Leviathan and the Air Pump; Historical Conditions of Possibility for the Emergence of Scientific Concepts and Objects; Hackinian Project of Styles of Scientific Thinking & Doing; Laboratory Style; Intervention into Nature and Creation of Phenomena; Realism of the Entities

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Introduction

In 1985 Steven Shapin and Simon Schaffer published *Leviathan and the Air Pump: Hobbes, Boyle and the Experimental Life.* A decade previously Ian Hacking had published *The Emergence of Probability* (1975) and in 1983, *Representing and Intervening* (1983), a manifesto for the study of experimental science and the role of experiment.

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In *The Emergence of Probability,* Hacking analyzes the historical conditions that made the emergence of probability around the year 1660 possible as a result of a mutation of preceding Renaissance conceptions. A comprehensive analysis of Hacking's work allows us to identify the centrality and persistence of certain themes and interests, which have been present from the beginning of his intellectual career and which serve as common threads linking together his different, seemingly unfocused projects. One of these threads, which weaves the web that constitutes Hacking's work, is his interest in the analysis of the historical and situated conditions of the possibility of the emergence of scientific concepts and objects. This idea, which Hacking adopts and adapts to his own interests, is a result of the influence of the thought of Michel Foucault.

In *Representing and Intervening,* on the other hand, on the basis of his emphasis on experimentation and manipulation, Hacking analyzes the historical and situated conditions of the possibility of the emergence of phenomena in the laboratory. These include phenomena that, like the laser, do not exist until they are created in the experimental cabinet. The text is a philosophical study of the role of experiment in science, in which the author aims to invert the traditional hierarchy of theory over experiment and show that the latter has a life of its own, independent of theory. Experimentation as intervention, as manipulation of the world, is used in this text by Hacking as an argument in favor of entity realism. Through his two most famous examples, the electron and the microscope, Hacking illustrates the importance of doing in scientific practice. Doing allows for the creation of phenomena and greatly favors a strong scientific realism.

Hacking's work can be structured around four fundamental nodes: probability, experimentation and scientific realism, making up people, and styles of scientific thinking & doing (Martínez 2021). It is the latter that will be fundamental for the objectives of this paper. Hacking presents styles of scientific thinking & doing as units, long-range conceptual frameworks that provide the historical conditions that enable the emergence of concepts, objects, classes, evidence, laws, and ways of telling the truth, specific to each style. These are the different general methods of scientific work, the ways of investigating that human beings have shaped to understand and change the world, which can be recognized since ancient times, have solidified over the centuries, and are still practiced today.

The four aforementioned nodes share, in addition to an interest in analyzing the historical conditions of the possibility of the objects and concepts that correspond to each style, a series of interconnections that result in the framework that constitutes Hacking's work. Thus, for example, the style of scientific thinking & doing is exemplified by the probabilistic style—which Hacking analyzes in *The Emergence of Probability* —and by the statistical style—which he addresses in *The Taming of Chance* (1990)—but in turn, it is an attempt to resolve and generalize theoretical questions that arise from the study of these examples. Likewise, the style, based on its characteristic of introducing new objects and kinds, is what provides the conditions of possibility for the emergence of, for example, new kinds of people, and in that sense, making up people. This last notion, in turn, occurs in the context of the statistical style, noting that statistics constructs new kinds at different times, and, in that sense, new people. On the other hand, there is also a strong relationship between the style of reasoning and experimentation and scientific realism, insofar as the style constitutes the space, not only for the realism-antirealism debates to be presented, due to its capacity to introduce new objects and the corresponding classifications for said objects, but also for experimentation and the subsequent creation of phenomena. The centrality of the styles project in the Hacking proposal leads us to think of them as a basal node of the same, to which all the others are related in some way or another.

Hacking took historian Alistair Crombie's list of styles of scientific thinking as a starting point for his analysis of styles, but modified it to suit his own objectives. Within this framework, he proposed what he called the laboratory style of thinking & doing,

characterized by the construction of apparatus to produce new phenomena, to create phenomena that do not previously exist in nature.

Leviathan and the Air Pump represents a story of unparalleled value for illustrating and working on several of his fundamental projects. It is the story of the historical conditions that made possible, in the 17th century, the emergence of the laboratory style of thinking & doing, based on the creation of a device in the experimental cabinet with which to intervene in the world and create new effects in nature. In his texts, *The Emergence of Probability* and *The Taming of Chance,* Hacking explores the conditions that made the emergence of the probabilistic and statistical styles possible. These investigations constitute not only examples or particular cases of the application of scientific styles of thinking & doing, but also constitute the historical background that inspires his notion of a style of scientific reasoning that reveals their characteristics and functioning in practice. In *Leviathan and the Air Pump*, on the other hand, Hacking finds the historical background for this new style, the laboratory style, that he adds to Crombie's list of styles and which completes the triad of styles to which Hacking dedicates some argumentation in his work.

This paper begins by presenting Hacking's proposed styles of scientific thinking & doing, then focuses specifically on his characterization of the laboratory style. It concludes with an analysis of Hacking's use of the history of Hobbes, Boyle, and the vacuum pump to illustrate his aforementioned projects.

Styles of Scientific Thinking & Doing

Although his book, *The Emergence of Probability,* can be considered an anticipation of his project on styles of scientific reasoning, Hacking locates the beginnings of this project in 1982 with the article "Language, Truth and Reason". However, it is in "'Style' for Historians and Philosophers" (1992a) that Hacking gives an account of its fundamental characteristics and of the main influences on his proposal. This was the work of both the Australian historian Alistair Crombie and Michel Foucault. He points out that he adapted, for metaphysics and epistemology, Crombie's idea of styles of scientific thinking in the European tradition, although changing its name to styles of scientific reasoning because he considered that "reasoning was a slightly less mentalistic gerund than thinking" (Hacking 2010, 21, 9), "with more connotations linked to investigation and Discovery" (Hacking 2003, 543). Hacking understands that style implies not only argumentation, but also manipulation and intervention, something that is not only mental and private but also public, that is not only talking but also arguing and showing (Hacking 1992a, 3). However, the chosen expression failed to accurately represent Hacking's goal of including not only the thinking but also the doing of scientific practice. Thus, in 2010, he stated: "Science is as much a matter of activity as of thought. Since I want to emphasize action and intervention, I speak of styles of scientific thinking & doing". (Hacking 2010, 21, 3) The new expression more accurately represents the idea that Hacking defended and the interests and objectives he pursued from the beginning of his style proposal. These have to do not only with thinking but also with doing and manipulation in scientific practice. Humans are embodied creatures who use both the mind and the body to think and act in the world (Hacking 2012, 600). We think with our hands, our bodies (Hacking 2014, xiv). As Sciortino (2023) maintains, for Hacking, developing the project on styles involves not only explaining how we have come to know the world, but also how we have altered it. Styles are ways of thinking, but also of intervening; they are ways of discovering things, but also of discovering how to change them (Hacking 2012, 601).

Doing is an essential element in all styles. It is present even in those styles that seem more difficult to visualize. For example, in his text, *Why is There Philosophy of Mathematics at All?* (2014), in which he addresses issues related to mathematics, one of the six proposed styles, Hacking emphasizes that one of the functions of mathematics is to do things. We think, we speak, we gesture, we make diagrams. Hacking thinks of mathematics as

something that is done in a material form (2011, 12; 2014, xiv), as involving activities grounded in the body, both in the hands and the brain, carried out by human communities at specific times and places and that, when applied, can be used in the material world. Similarly, in the case of the statistical style, seemingly descriptive and resulting from mere enumeration, it is clearly evident, according to Hacking, how the development and growth of a reasoning style is a matter not only of thinking, but of doing (1990, 6). Descriptive censuses, for example, are extremely complex; the census must be organized, censors chosen, a code invented, tests invented to find censors who falsify numbers, etc. All these activities integrate reasoning, which is a way of thinking and doing. The data are recorded, collected, moved, organized, and systematized.

The objective of this project of Hacking's is to make a genealogy of scientific reason, "how we found out how to find out" (Hacking 2010, 21, 3), so as to analyze the various general methods of scientific work that can be recognized from antiquity to the present, the different forms of research that have enabled human beings to dominate the planet.

He proposes the scientific style of reasoning as "a new analytical tool that can be used by historians and philosophers for different purposes" (1992a, 1); it is capable of bridging the gap between social studies of knowledge and philosophical-metaphysical conceptions of truth, existence, logic, meaning, etc. It is an enduring and impersonal social unit, the intellectual preparation or availability of a particular way of seeing and acting. It is an anonymous and autonomous system of thought, not constituted by the beliefs of a single person or school.

Style does not determine a specific content or science, but rather represents distinct forms of research that can, on the one hand, be deployed complementarily in any scientific discipline, but, on the other, be shared by different sciences. Style is not identified with or exclusive to a particular science or a scientific community, but rather permeates all of them. Styles should not be conceived as isolated entities, but rather as compatible and complementary, interacting with each other, although Hacking does not explain or provide any examples of how this integration of styles is achieved in practice. Nor is style specific to a particular period.

As noted above, Hacking takes the six styles of scientific thinking in the European tradition proposed by Crombie (1988, 10-12) as his starting point for his work.[2] Although he maintains that Crombie's work provides a useful historical account for characterizing his style of reasoning, he departs from it in some respects. First, as already stated, he prefers to use the term "reasoning" instead of "thinking," since he considers the style to involve not only argumentation but also manipulation (Hacking 1992a, 3). Nor is he satisfied with this list, first, because he is seeking a history of the present, because what is important now may be different from what was important before, and, second, because it is not an exhaustive list, as it does not record other styles from earlier times or outside the West. As a result of these differences, Hacking proposes his own list of styles of scientific reasoning:

1) The method of demonstration in mathematics
2) Experimental exploration and measurement

2. The six styles proposed by Crombie are: (a) The simple method of postulation exemplified by the Greek mathematical sciences; (b) The implementation of experiment both to control postulation and to explore by observation and measurement; (c) The hypothetical construction of analogical models; (d) The ordering of variety through comparison and taxonomy; (e) Statistical analysis of regularities of populations, and the calculation of probabilities; (f) The historical derivation of genetic development (Hacking 1992a, 4).

3) Construction of analogical models by hypothesis
(2)-(3) A. Galilean style
2)-(3) B. Laboratory style, with creation of phenomena
4) Sorting by comparison and taxonomy
5) Statistical analysis of regularities in populations and calculation of probabilities
6) Historical derivation of genetic development (2006, Lecture May 9, 3)

To develop his notion of style, Hacking adds to the Crombian characterization the analysis of metaphysical aspects, the microsociology of origins, and philosophical anthropology. Style includes metaphysics because there is a set of novelties that are an integral part of each style: new types of objects, evidence, statements that cannot be uttered before the existence of the style, laws, possibilities, new types of classification, and explanation. Style is a condition for the emergence of certain distinctive objects, which are individualized on the basis of the style and are not previously evident. This emergence is simultaneous: the style does not emerge first, and then a new type of object and a new method of reasoning are introduced. Styles are constituted by their methods and the types of objects with which they deal.

The emergence of a new domain of objects of study generates an ontological dispute, a debate about what exists. It follows that ontological debates only take place within a particular scientific style. The debates between realism and anti-realism make no sense, according to Hacking, except in the context of a style of reasoning.

Style is also social. Hacking believes that the microsociological aspect, the circumstances in which a style emerges, must be taken into account. A style is situated within a network of people, responding to the needs, interests, or curiosity of some of them. It begins as driven by social vectors and is inseparable from the institutions that develop and enable it. Social analysis is important to explain not only the origin of each style but also its continuation, expansion, and revitalization. In this sense, styles are contingent, made possible by historical, institutional, economic, and other conditions. However, as a style matures, it responds less and less to these interests and conditions, so that its stabilization techniques become autonomous as the style develops and strengthens, until it no longer needs contextual support or rhetoric to generate its own norms. The existence of such stabilization techniques is a prerequisite for a style to produce a relatively solid body of knowledge, ensure openness, creativity, and the capacity for self-correction, and engender new knowledge and applications. (Hacking 2006, Lecture May 9, 3)

Finally, the study of scientific rationality also has an anthropological component. Each style is based on innate, universal human capacities, which are discovered, exploited, and developed in specific historical situations, and are utilized differently in different historical contexts. Thus, styles are the product of cognition and culture, of the interaction between, on the one hand, human endowments that are the results of our evolutionary heritage and, on the other, specific historical events and developments. As human culture develops, we learn how to use these abilities in entirely new ways. We learn to inquire.

As mentioned earlier, a style establishes, for its own domain, the meaning of the statements that belong to it. Certain statements can only exist within a given style. It is this style that provides the space of possibilities for the emergence of objects and concepts and, therefore, of the statements that deal with them. The emergence of a style makes certain statements positive. This idea of positivity is perhaps one of Hacking's most frequent references when pointing out his debt to Foucault. Archaeological history allows us to establish what Foucault calls positivity, a space in which it is possible to determine whether Buffon and Linnaeus were speaking of 'the same thing,' deploying 'the same conceptual field,' opposing each other on 'the same battlefield.' (Foucault 1972, 126). Positivity is the historical-empirical substrate of discourses, the set of material conditions that make possible the existence of discourses as specific practices. A discourse always possesses material

conditions of enunciation that go beyond its lexical or logical rules. Such rules imply the mode of its existence, its enunciability, transmission, appearance, and disappearance. This concept of positivity is not a transcendent principle; it is not Kant's absolute a priori, whose conditions were universally applicable, necessary constraints for all possible experience. It is an a priori relativized by history. Its conditions are contingent on the particular historical situation and change according to time and domains of knowledge. It is not a condition of validity for some judgments, but a condition of reality for some statements, for their emergence, their way of being, their transformation, their subsistence, their coexistence with others. It is a condition of a history that is already given, which is the history of things actually said. (Foucault 1972, 127).

Style determines which statements can be candidates for truth-value. A proposition can only be deemed true or false, according to Hacking, when we have ways of reasoning about it and when there is a style that helps determine its truth-value. However, there are statements that have truth conditions independently of style, for which a correspondence theory of truth will provide their meaning. Hacking has no objection to a correspondence theory of truth whose terms designate basic-level concepts, which can be called pre-style statements. However, there are a number of questions about which it only makes sense to ask questions within acceptably reasoned ways of answering them. What determines the truth-value of a proposition are the methods, the way of thinking and acting, the type of evidence of the style. Each style determines the criteria of truth-telling that apply in its own domain.

Each style becomes a standard of objectivity because it has the virtue of producing truth (Hacking 1992b, 135). This does not imply, Hacking argues, some kind of relativism; that styles are self-authenticating (Hacking 1992a, 13; 1996, 73-74) is part of an explanation of what he calls objectivity. Each form of research entails its own standards of evidence, criteria for proof, and demonstration. A style is not relative to anything. It does not respond to some preexisting criterion of objectivity or determine the standard of objective truth. It is the standard.[3]

Hacking sees his project as a continuation of the Kantian project of explaining why objectivity is possible, but at the same time as a deviation, because Kant did not think of scientific reason as a historical and collective product; Hacking, by contrast, does (Hacking 1992a, 4).

Note that Hacking prefers to speak of reasoning and truthfulness rather than of reason and truth because while rationality and truthfulness have a history, reason and truth lack one. Hacking borrows the notion of truthfulness from Bernard Williams (2002), who argues that the concept of truth is universal: it has no history. Truthfulness, however, does have a history. In history, telling the truth about new kinds of things in new ways and in response to new standards becomes possible. According to Hacking, Williams's proposal can perfectly explain how styles originate, crystallize, and develop historically: a change in the conception of what it means to tell the truth about X occurs in century Y, and its icon is Z. A real change in the conception of what it means to tell the truth about something is a profound revolution. However, those who act in accordance with the new style are no more rational or better informed than their predecessors (Hacking 2006, Lecture April 27, 9).

Some historians, such as Crombie, maintain the continuity of theoretical frameworks and see no room for radical shifts. Others, on the other hand, see mutations and consider that there is no room for continuity. Hacking is eclectic; he takes continuity in a particular way, which includes mutations and catastrophes. In history, radical changes in knowledge

3. Despite Hacking's assertions, it is not clear that his project of styles does not imply relativism. Considerations on this issue are not unequivocal. (Martínez 2021, 40)

and styles of reasoning can be observed, sharp discontinuities in the ways in which knowledge is acquired. While there is room for both continuity and discontinuity in styles of reasoning, the emphasis is on the former. On the one hand, styles are stable, cumulative, and immune to any kind of refutation. They evolve, assimilate, and integrate. Styles of reasoning that were once fundamental accumulate and then take on a less central role, making possible the expansion of human knowledge: "[...] how much of a science, once in place, stays with us, modified but not refuted, reworked but persistent, seldom acknowledged but taken for granted" (Hacking 1992, 29). However, these long-term processes are interrupted by crystallizations and radical changes that give rise to discrete periods within that continuum. Every style of reasoning has at least one moment of crystallization, a fixation point for how to proceed in the future, which usually occurs after centuries of rudimentary precursors and is linked to particular emblematic events. Crystallization is a catastrophic event, in the sense that it changes things forever and in a short period of time. The emergence of modern probability, around 1660, as a result of a new configuration of ideas that was previously not even thinkable, is, according to Hacking, a clear example of crystallization. Now, to say that it's an event that changes things forever doesn't mean that probability, in this case, becomes a solid, unchangeable crystal. It means that it's irreversible, a point from which there is no return. It's a radical change because it introduces new objects and criteria for the truth and falsity of statements about those objects. Crystallizations are generally associated with iconic figures such as Pascal in the probabilistic style, Linnaeus in the taxonomic style, Galileo-Husserl in the hypothetical modeling style, Darwin in the historical derivation of genetic development style, Boyle in the laboratory style, although each of them is, at the same time, nothing more than a player in that *way of life* that is the style. Only when a style crystallizes does one understand how to investigate things using it.

Hacking's idea of discontinuity is clearly and early influenced by Foucault's idea of breaks in systems of thought, as expounded in *The Archaeology of Knowledge*. According to Foucault, the point is to detect the incidence of interruptions in thought (1972, 4), to emphasize the central role that discontinuity plays in its history. Breaks and dispersions are not mere accidents but rather one of the fundamental laws that regulate discursive behavior.[4] However, there are also points on which Hacking himself expresses his distance from Foucault. One of these is related to the fact that he has a Braudelian conception[5] of style, unlike Foucault's proposal, which does not. This means that while style is evolutionary and can even be eternal, Foucault's episteme is born and dies in two moments of transformation. The episteme is a space of knowledge that was established once and for all, and if it disappears, it will do so once and for all and will necessarily be replaced by another. Styles, however, can be abandoned without being supplanted by another.

4. Foucault's emphasis on discontinuity does not mean, however, that there is no room for gradual transformations or continuous developments. Discontinuity is not total, since theories and practices are never independent of what has gone before. What remains, what persists, is usually re-stated, reformulated in the vocabulary of the new discursive formation.

5. Fernand Braudel's conception of history is one of long duration, of slow rhythms that regulate the time of the economy, but also of states, societies, and civilizations. He considers the short span of our lives to be merely the surface of the present, the political, economic, cultural, social, and other events beneath which lies a history that stagnates, that marches slowly, a structural history that resists time, that endures and even lasts. For a deeper understanding of this aspect of Hacking's proposal, see Martini 2023.

The Laboratory Style of Thinking & Doing

As already noted, Hacking starts from Crombie's list of thinking styles, but goes on to present his own. One of the modifications he proposes to Crombie's list is the inclusion of the scientific laboratory style. At this point it is worth clarifying that although Hacking initially presents it as a new style, in "Language, Truth and Reason" 30 years later (2012) he maintains: "I once wrongly suggested that we add 'the laboratory style' to Crombie's list, as a style that builds apparatus in order to elicit or create new phenomena, rather than by exploring and measuring what is already there to be found. The advent of the laboratory is a radical eruption, but Occam's razor moves us to regard it as a crystallization within Crombie's second style, rather than as a new style" (603). And he adds "although experiment has a life of its own, laboratory work without hypothetical modeling would be as worthless as the frantic collecting of Francis Bacon's ant in his parable of ant, bee, and spider (Aphorism XCV of the Magna Instaurstio). And hypothesis without experiment are like the spider. Scholars no longer appear to speak of the scientific method, but until quite recently it denoted the bee, who combines the talent of ant and spider". (604)

According to Hacking, the laboratory style is the most powerful style of reasoning, one that has not only made the modern world possible but has also enabled its permanent transformation. Let us recall the importance that Hacking places on doing in scientific practice. This is evident in early texts such as *Representing and Intervening*. That text, in particular, aims to vindicate the value of experimentation in scientific practice. In this sense, Hacking proposes inverting the traditional hierarchy of theory over experimentation and showing that the latter has a life of its own, independent of the former. This means, among other things, as Rouse (2002, 264) asserts, that the material practices of experimentation are not merely means for observation, but always involve executions and skills that must be understood as possessing their own scientific significance; that experimental work does not simply test theories, but, on the contrary, responds to objectives, opportunities, and constraints that arise within experimental practice; that the philosophical significance of experimental practices and their results is neither limited nor determined by theoretical interpretations; and that experimentation frequently produces new, artificial phenomena, whose occurrence is not the exemplification of more general natural laws. That is, the fundamental objective of science is not to explain the world, but to transform it. In this sense, the goal of experimentation is not the mere testing of theories, but the creation of new phenomena, which do not exist until they are created in the laboratory.

The laboratory style is a combination of two of the styles mentioned in Crombie's list. These are b. the deployment of experiment both to control postulation and to explore through observation and measurement and c. the hypothetical construction of analogical models. It does not, however, supplant them. Although these alone cannot explain the refinement and sophistication that the experimental method has developed, there are fields of specialization in which both experimentation and hypothetical modeling continue to be used.

According to Hacking, the laboratory style is characterized fundamentally by the construction of apparatus to produce phenomena. It provides the historical conditions making possible the emergence, in the laboratory, of objects, statements about them, evidence, laws, possibilities, and new types of classification and explanation that refer to them. Its core is the construction of instruments designed not only to examine but also to intervene in the world, to create new phenomena. The laboratory is an institution in which one works with phenomena that rarely occur in a pure state before being constructed there under surveillance and control.

The most unusual feature of styles, according to Hacking, is their capacity for self-authentication. Each style is the standard of *good reasons* in its particular field of research.

This self-authentication and/or self-vindication[6] is the cornerstone of objectivity, and in the laboratory, of reproducibility. The introduction of new kinds of objects and new ways of verifying statements about them is a source of stability for the sciences. In the case of the laboratory style, its stabilization technique is not a mental or social construct. It is material. It has to do with the relationships between thoughts, actions, and technical productions. A theory predicts something that can be observed at a particular time and place (Hacking 2006, Lecture May 9, 7).

In line with what was pointed out about truth in the previous section, Hacking considers that there is no single theory of truth or semantics that applies to the entire set of empirical sentences investigated in science. The truth status of some statements is determined by the ways in which they are reasoned about. In the laboratory, conjectures are not formulated and subsequently tested for truth. Devices are invented that produce data and isolate or create phenomena, for which a network of theories at different levels is true. Moreover, phenomena can only be considered as such when the data can be interpreted in light of the theory. Knowledge is true if it fits the data generated and analyzed by instruments and devices shaped by topical hypotheses. In this way, a tailor-made fit develops between ideas, devices, and observations, a coherence between thoughts, actions, materials, and markers. And it is the style of reasoning, the laboratory style, that establishes this. In "The Self-vindication of the Laboratory Sciences" (1992), Hacking argues that laboratory sciences tend to be self-justifying, producing a self-vindicating structure, with the idea that a mature laboratory science develops a body of mutually adjusting types of theory, apparatus, and analysis (30).

Hacking draws up an inventory of the laboratory's "inhabitants." This is a list of internal elements[7] that contribute to the laboratory's style, arranged in three subgroups: ideas (questions, background knowledge, systematic theory, topical hypotheses, modeling of the apparatus), things (target, sources of modification, detectors, tools, data generators), and marks or inscriptions (data, data assessment, data reduction, data analysis, and data interpretation). All these elements have one thing in common: they are plastic, potentially modifiable resources. Each of them can be molded and adapted to fit with the others, to lead to some kind of agreement. (Hacking 2006, Lecture May 9, 13) Usually, there is no preexisting phenomenon that informs the experiment. Phenomena are constructed. Theories in laboratory sciences are not directly compared to the world. (Hacking 1992, 30), but with equipment that has evolved alongside them and with certain modes of data analysis. Theories persist because they are true with respect to phenomena produced or created by the apparatus in the laboratory and measured by instruments also designed by humans. There is no pre-arranged correspondence between theory and reality that must be confirmed. Theories are at most true for the phenomena obtained by instrumentation in an attempt to achieve a good fit with the theory. They are true for the laboratory phenomenon. The process of modifying the work and the instruments—materially and intellectually—provides the glue that holds the intellectual and material worlds together. It is what stabilizes

6. Hacking uses the term self-authentication to mean the way a style of reasoning generates the truth conditions for its own propositions. He understands self-vindication as the way ideas, things, and marks fit together in the laboratory. Thus, self-authentication is a logical concept, while self-vindication is a material concept (Hacking 1992, 51, note 2).

7. Hacking acknowledges having omitted other elements of laboratory science from his list, such as the worldview (themata, styles, paradigms); the experimenters, their negotiations, their communications, their environment, the buildings in which they work, the institutions that pay their bills; the authors, the authority, and the audience. He has omitted these and limited himself to what he calls an internal list, "because I am concerned with elements that are used in the experiment." (Hacking 1992, 51)

science.

Throughout history, some styles have been displaced or abandoned, such as Renaissance medicine or certain astrological doctrines (Hacking 1982, 60). However, according to Hacking, this does not prevent us from understanding them. This understanding is not exactly a translation but rather the learning of chains of reasoning contextualized so that they make sense. Understanding is learning how to reason. It is, therefore, misguided to focus on the translation of texts, which is difficult when one encounters new ranges of possibility that make no sense for the style of reasoning that flourished or flourishes in another culture. Hacking differentiates his idea of a style of scientific reasoning from Thomas Kuhn's notion of incommensurability, closely related to the notion of translation rather than to that of reasoning. Nothing in Hacking's project leads to semantic incommensurability. In any case, what is subject to revolution, mutation, and forgetting is knowledge, but not the way in which it is obtained. Some styles have been completely displaced, and while their systems cannot be translated, their chains of reasoning can be learned. The translation of truth is irrelevant; what matters is the communication of the meanings of thought. The unit of analysis of conceptual change is not the meaning of terms and concepts. It is not conceptual change itself that is of interest, but rather changes in the function that concepts generally serve in certain settings and times.

However, the fact that there is no incommensurability between theories does not, according to Hacking, prevent it from existing in the laboratory, because the instruments appropriate for one theory are inappropriate for another. This is a scientific fact that has nothing to do with "meaning change" or other semantic notions associated with incommensurability. (Hacking 1992, 56-57) Incommensurability, for Hacking, is found in the fact that there is no body of instruments for making common measurements because the instruments are peculiar to each theory. The use of more powerful instruments, for example, may result in the production and conceptualization of new types of data that do not fit the level of precision of which the previous or established theory is capable. A new theory with new types of precision is needed. This new theory will be instrumentally incommensurable with the previous one. Now, can they both be true? They could not be if one assumes that there is a single true theory that corresponds to the world. But there is not. The mutual maturation of a new theory and experiment does not dislodge the old, established theory, which remains true with respect to the data available in its domain. The various theories, which persist at different levels of application, are true for different phenomena and data domains.

Hobbes, Boyle, the Vacuum Pump, and the Emergence of the Laboratory Style

A decade after the appearance of the book *The Emergence of Probability*, in which Hacking analyzes the historical conditions making possible the emergence of probability and the probabilistic style, Steven Shapin and Simon Schaffer published *Leviathan and the Air Pump: Hobbes, Boyle and the Experimental Life* (1985). The text, considered by Hacking as "an unparalleled vignette of the birth pangs of a new style of reasoning" (Hacking 1991, 240), illustrates the historical conditions of possibility of the emergence of the laboratory style. The fundamental characteristic of the laboratory style, that is, the construction of apparatus to produce new phenomena and/or effects, is reflected in Shapin and Schaffer's book in the form of the construction of the air pump with the aim of investigating the capacity of air to exert pressure.

According to Hacking, the authors show the material circumstances in which the laboratory style crystallized. As already noted, the crystallization of styles is generally associated with an icon, some legendary, pioneering figure. In this case, Robert Boyle (1627-1691) and his apparatus are emblematic of the crystallization of the laboratory style. Hacking

acknowledges, however, that his choice of Boyle as an icon is none other than the choice of his preferred myth. Historians of science often point out that the person who truly inaugurated the way of life at the heart of the laboratory style was not Boyle but Robert Hooke (1635-1703), his colleague and assistant, whom Boyle asked to construct an air pump, a closed container from which air could be extracted using a pump mechanism. Others note that there was another, more suitable technical device, not in London but in Padua. None of these statements, Hacking believes, has any relevance to the myth. The important thing is that at that time, researchers built a device that produced a new phenomenon: the vacuum. It was a device created in the laboratory, with which one can intervene in the world, produce effects in another part of nature, and thus argue in favor of the reality of that theoretical entity. Hacking's choice of myth also has to do with another of his interests: the debate over realism. Thus, he states, "Of course, there were laboratories before Robert Boyle. There are other great men and other great names. Galileo himself built an extraordinary device to study motion and acceleration on an inclined plane. We also think of Torricelli. My favorite myth is Robert Boyle and the air pump, in 1660. But I am addressing a problem closely linked to the controversies that shook the philosophy of science in the 1980s and that continue today [2006] with almost the same vigor. These are debates over scientific realism, which refers to objects and structures that, in principle, are inaccessible to observation. The so-called theoretical entities." (Hacking 2006, Lecture April 27, 8) The air pump is a device used to demonstrate the existence of an unobservable entity, the vacuum. In Boyle's time, many people, especially Thomas Hobbes (1588–1679), who, in the book, takes the role of being his opponent, denied, following the continental tradition, the possibility of the existence of a vacuum. (Hacking 2006, Lecture April 27, 8–9)

Now, for Hacking, the true hero, or rather heroine, of this story is the device, the vacuum pump, which creates effects, in isolation, that do not previously exist in nature (Hacking 1991; 2009). It is the device that inaugurated laboratory science, one that marks the beginning of a new way of life, the beginning of the academies of science, of the space we call the laboratory, populated by the technical devices that are the true inhabitants of laboratories. (Hacking 2006, Lecture April 27, 16) Until that moment, there had been devices to measure or explore phenomena, as is the spirit of the second style proposed by Crombie: the use of experience both to test postulates and to participate in explorations through observation and measurement.

The main character in Shapin and Schaffer's book is an innovation. The experimental program, developed in the 17th century, represents a radical change, a catastrophic event, in the sense that it changes things forever and in a short period of time, while also establishing a set point for how to proceed in the future. Boyle and the air pump, Hacking claims, "began a journey in physics that no one had anticipated. This is the first step on our journey into the void, where the secret of the forces of nature lies (according to physicists Davies, Milonni, and many others)." (Hacking 2006, Lecture April 27, 18). This radical change is the result of introducing a novelty into the way human beings know: the use of experimentation and hypothetical modeling within the framework of a new institution, the laboratory.

The word laboratory originally refers to the *laboratorium*, in the Middle Ages, understood as the often secret cabinet of an alchemist. Shapin and Schaffer present the laboratory, in the context of the birth of experimental science, as opposed to the alchemists' cabinet in that it constitutes a public space (2011, 56, 78). It is a space for "the public constitution and validation of knowledge" (2011, 78), "a disciplined space, where experimental, discursive, and social practices were collectively controlled by competent members" (2011, 39), which contrasts, "on the one hand, with the private work of the alchemists, and, on the other, with the individual dictates of the systematic". (2011, 78) However, Hacking states, "The laboratory was to be a space at once open and shut". (Hacking 1991, 235) It is public because any work carried out in a laboratory can be reproduced and checked by another researcher with the appropriate tools. But it is also

private because, as Hobbes points out, only a carefully selected elite, the members of the new Royal Society of London, were allowed access to the laboratories and demonstrations of scientific societies. (Hacking 1991, 239) As Shapin and Schaffer themselves argue, "It was public in a very precisely defined and very rigorously policed sense: not everybody could come in; not everybody's testimony was of equal worth; not everybody was equally able to influence the institutional consensus" (2011, 78) Only the right people, the authorized people, the gentlemen, are capable of judging the outcome of an experiment. (Shapin and Schaffer 2011, 335-336; Hacking 2006, Lecture April 27, 15) Only the opinion of those who knew how to understand how an instrument works and followed certain conventions could contribute to the validation of knowledge (Sciortino 2023, 126).

The laboratory is both the manifestation of the beginning of a new way of life and the structure that facilitated its establishment. It is the place where that way of life can be lived. It is the spatial inscription of the sciences. It is a space inhabited by the public (albeit restricted), but above all, according to Hacking, inhabited by instruments, by apparatus. Devices are essential to the laboratory, both for the creation of phenomena and for measurement and other purposes of the laboratory. This is why, in Hacking's view, the hero of Shapin and Schaffer's book is not Boyle or Hobbes, but the device itself. The book is the biography of a device.

In this new workspace, scientists seek answers to questions about the world, using the plastic resources mentioned in the previous section. Its most innovative feature, the innovation of this way of life, is the production, purification, and above all, the creation of phenomena. It is indeed the space where one thinks, but fundamentally where one does things, where one investigates by doing, manipulating, and intervening, creating a new phenomenon: the void.

The idea of creating phenomena in the laboratory, as emphasized, is a fundamental pillar of Hacking's approach. Within this framework, *Leviathan and the Air Pump* is not merely the story of a scientific incident, nor of the confrontation between two characters, Hobbes and Boyle, followed by a revolutionary outcome. The book focuses on a new type of actor, a new type of place, a new type of writing, and a new type of fact (Hacking 1991, 235; 2006, Lecture April 27, 13).

In *Representing and Intervening,* Hacking emphasizes phenomena that do not exist in isolation, but require special devices to be produced. This activity became routine in scientific research beginning in the 17th century. It is in this sense that in *Leviathan and the Air-Pump,* the authors defend "the thesis that in the late 1650s Boyle and the English experimental community, still in its infancy, established new rules of discourse by which matters of fact had to be both generated and defended." (Sciortino 2021, 134) Before the invention of the pump, researchers tried to make sense of the phenomena observed in nature. Then, a new kind of science responded to a new kind of master: phenomena that occur over a short period in the artificial conditions of the laboratory. (Hacking 2006, Lecture April 27, 14) Boyle created a phenomenon, the vacuum, in a bottle, in a glass container. A vacuum is unobservable; it cannot be seen; only its effects are seen. You see the candle go out, the dog locked in an airtight box weakens and dies. According to Boyle, the explanation is clear: the pump draws air from the box in which the candle burns, and in which the dog breathes. For Boyle, it's obvious. Of course, nature abhors a vacuum, but human genius has created a device, a pump, that can suck the air out of the box almost completely.

Now, why create artificial phenomena? This is the question Hobbes asks in *Dialogus physicus* (1661), in response to Boyle's *New Experiments* dating from 1660. (Hacking 2006, Lecture April 27, 14) Hobbes thinks that we do not need to create artificial phenomena, "we have quite enough phenomena already, thank you very much, he wrote". (Hacking 2002, 15) Hobbes intuited that laboratory devices capable of producing phenomena were a radical novelty and he was absolutely against that way of doing science, that way of life that could

"destroy the metaphysics, epistemology, and the approach to science that he held so dear." (Hacking 2002, 15) The creation of phenomena frightened him.

While Renaissance debates between demonstration and observation may sound familiar, Hacking argues, the battle between Boyle and Hobbes was not merely a dispute over the relative weight of empirical versus deductive proof. It dealt with a deeper and more consequential issue: what counted as evidence. "What do we admit as factual evidence? Is it what we find at home, what is the report of the stranger, or what is revealed in the skies? Or is it what we make with machines?" as Boyle proposed. (Hacking 2006, Lecture April 27, 14; 2009, 114–115) The focus of the debate is on whether one should participate in a laboratory style where an apparatus is used to create new phenomena. For Boyle and his community, evidence is not only what can be found as a given in nature, but also what can be done, what can be created. Hobbes does not accept the new practice of acquiring knowledge that was being imposed on scientific inquiry, with its conventions and new standards of truth. Hobbes could see, from the outside, as a contemporary but external observer, the characteristics of the style that was emerging and did not accept them; he "saw that this was a new and threatening style of reasoning." (Hacking 1991, 240) He did not accept the new kind of evidence provided by the laboratory style and denied reliability to Boyle and his community. "Hobbes saw exactly what Boyle was doing, and he hated it." (Hacking 2009, 114) He argued that all experiments conceal theoretical assumptions whose validity could always be questioned, and he continued to defend the simple method of postulation exemplified by mathematics as a model of knowledge.

Hobbes ultimately lost the battle; the new style emerged. This emergence was made possible by the availability of this new type of evidence, the creation of effects. Similarly, according to Hacking, probability could only emerge when a new type of evidence, factual evidence, became available. Hacking argues, in *The Emergence of Probability,* that it was only around 1660 that many of the necessary ingredients coalesced to form the space in which probability, with its dual nature as we know it today, emerged. Around this time, many people arrived independently at the basic ideas about it. Although there were some anticipations, the lack of a pertinent concept of factual evidence,[8] the formation of which is one of the preconditions of probability, prevented its emergence until that moment. (Martínez 2021)

The laboratory style emerges as a new way of thinking, a new way of doing, in which a new type of evidence is accepted, new forms of proof, but also new questions, are asked in a new type of discourse appropriate to experimental philosophy (Shapin and Schaffer 2011, 45), and above all, new ways of telling the truth are developed. "Boyle produced a vacuum, but also new ways of telling the truth about such theoretical items". (Hacking 2009, 127-128) Boyle and the laboratory style changed the conception of what telling the truth is, by using new instruments to create new phenomena and establish new statements about them. *Leviathan and the Air Pump* offers an unparalleled insight into this issue, showing how Hobbes

8. By the relevant concept of evidence is meant the evidence of things or internal evidence, distinct from the evidence of witnesses and authority. In medieval times, an opinion was considered probable if it was approved by the old authority, or at least well attested. In the Renaissance, a new kind of testimony was accepted: the testimony of nature, which, like any other authority, had to be read. Nature, then, could confer factual evidence—in the modern sense of the atomic, isolated, independent fact, which can serve as an indicator, and even as positive proof, of another, isolated, independent fact. But, since it was based on natural signs, it could only sometimes be trusted. Probability communicated itself through what are now called law-like regularities and frequencies. Thus, the connection of probability with stable, law-like frequencies is a result of the way the new concept of internal evidence came into being. Thus, only once the sign is transformed into evidence is the space of possibilities given for the emergence of a dual concept of probability.

recognized that Boyle and his colleagues had introduced a shift, not only in the question of the creation of phenomena and evidence, which has already been addressed, but also in the conception of what it means to tell the truth.

What is the change in the conception of what it means to tell the truth about "theoretical entities"—that is, about objects and structures that are, in principle, inaccessible to observation—on the basis of the laboratory style? According to Hacking, it is no longer simply a matter of designing analogical models and using the hypothetical-deductive method to corroborate or refute them, but rather of using designs that, as we have seen, resort to the invention of devices with the purpose of purifying or even creating phenomena in the laboratory that do not exist in a pure state in nature.

As already noted, Bernard Williams (2002) claims that the concept of truth has no history. "The concept of truth itself—that is to say, the quite basic role that truth plays in relation to language, meaning, and belief—is not culturally diverse, but always and everywhere the same." (61) He denies that truth has a history, but argues that the criteria for telling the truth in a particular domain change over time. That is, truth does not have a history, but truthfulness does. Hacking's style project follows Williams in this regard. (Hacking 2012, 605) The emergence of a new style entails a change in conceptions of what it means to tell the truth about X. (Hacking 2004, 142) Thus, the birth of the laboratory style generated new candidates for truth or falsehood. There is a fundamental change in the conception of what it means to tell the truth about objects and structures that are in principle unobservable, which occurred in the mid-17th century, and its icon is Robert Boyle.

"The new way to find out is to build apparatus to create new phenomenon and to expose purified ones. There was, then,

(*) A shift in conceptions of what it is to find out about nature, and hence how to tell the truth about it.

(**) This significant change took place in the seventeenth century, and its best emblem is Boyle". (Hacking 2009, 116)

Hacking argues that most analytic philosophers would agree with Williams's proposal that truth has no history. Many other thinkers, for example, those fascinated by Steven Shapin's *A Social History of Truth* (1994), would disagree strongly. Hacking says he thinks that Williams might have thought the difference was more in the words than in the content. "He might have said of Shapin what he said of Foucault, that much of such 'work addresses epistemological issues, of what at different times counts as establishing truth in different fields' (Williams 2002, 300, n. 31)." (Hacking 2012, 605) Shapin's proposal does not necessarily conflict with those of Williams and Hacking, in that the idea of what truth is does not change over time. Hobbes and Boyle, in *Leviathan and the Air Pump,* agree, as Sciortino (2023, 142) shows, about the concept of the knower: for both, it was someone who possessed a true belief and a property X, no matter which one, that correlated well with it. (Shapin and Schaffer 2011, 130-131). Where they disagree is on which property X should be attributed to the knower: for Boyle, it was the property of possessing laboratory-style methods; for Hobbes, it was the property of possessing postulational-style methods. (Shapin and Schaffer 2011, 151-152) The difference between the two was not in the concept of what a true belief is but in who it could be attributed to, in who could be trusted. For Boyle, it was attributable to the experimenter: "If one wished to make experimental knowledge, then here [in the laboratory] were the technical, social, and discursive means with which it might be made. (Shapin 1994, 127) For Hobbes: "When its methods had been rightly followed, geometry yielded irrefutable and incontestable knowledge". (Shapin and Schaffer 2011, 100)

Final considerations

The paper attempts to show how *Leviathan and the Air Pump* constituted, for Hacking, the historical background against which and with which he illustrated and worked on several of

his fundamental projects. In his own research on probability and statistics, Hacking analyzes the historical conditions of the possibility of the emergence of certain scientific concepts and objects; in the same way, in Shapin and Schaffer's book, Hacking finds an analysis of the historical conditions that made possible, in the 17th century, the emergence of the laboratory style of thinking & doing. According to Hacking, the authors show the conditions under which the laboratory style crystallized. In this history, Hacking identifies Boyle and, above all, the vacuum pump, as the icon of that crystallization.

Why Boyle? Why the vacuum pump? What is the reason for this choice, whether it is a question of the man or the device? Hacking answers, "There is a practical reason: the existence of this fascinating book, which is, in several respects, a perfect source for reflection on the laboratory. The book by Simon Schaffer and Steven Shapin. In fact, it offers an unparalleled overview of this question." (Hacking 2006, Lecture April 27, 9)

The choice of Boyle is the choice of a myth, the choice of the myth Hacking prefers. Thus, as has already been indicated, he states, "There are other great men and other great names. Galileo himself built an extraordinary device to study motion and acceleration on an inclined plane. We also think of Torricelli. My favorite myth is Robert Boyle and the air pump, in 1660." (2006, Lecture April 27, 8) But why not Galileo, then? The answer is that the story of Boyle and the invention of the vacuum pump is not only related to Hacking's interest in analyzing the historical conditions of possibility of the emergence of the laboratory style, but also to at least two other fundamental projects belonging to his proposal: intervention into nature and the creation of phenomena as a fundamental characteristic of laboratory science, on the one hand, and the argument in favor of the realism of theoretical entities, on the other.

Hacking argues repeatedly (Hacking 1983; 1989) that, in branches of science such as astronomy or astrophysics, it is more difficult to argue—or there is no compelling argument—in favor of the realism of the entities with which they work. Although technology in these sciences has changed radically since ancient times, according to Hacking, their method remains the same: observe celestial bodies, construct models of the macrocosm, and try to make observations and models agree with each other. They remain the perfect paradigm of Alistair Crombie's third style: the hypothetical construction of analogical models. In them, there is no intervention, no creation of phenomena.[9]

In contrast, Boyle's laboratory represents the transition to the experimental method, which involves interfering with nature and creating new phenomena. It involves the invention of a device, the air pump, which creates an effect not previously present in nature, the vacuum, which is a theoretical entity. This new effect is unobservable, but one about which there are good reasons to argue its reality because it interferes with another part of nature: subjected to it, the candle is seen to go out, and the dog weakens and dies.

9. Hacking's position has been criticized by, among others, Dudley Shapere (1993) and Edwin Turner (1988). (Martínez 2021, 148).
It is also worth noting that, in response to these criticisms, in *Scientific Reason* (2009, 154), Hacking clarifies that his claim of anti-realism in these sciences should be understood in the following sense: his experimental argument for realism cannot be invoked for many of the entities they work with. This does not mean simply stating that these entities are definitely not real, but rather claiming that there are more compelling reasons for affirming the existence of polarized electrons than of gravitational lenses, for example.

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