HELLENIC REPUBLIC
National and Kapodistrian University of Athens

National and Kapodistrian University of Athens

Department of History and Philosophy of Science

&

Department of Informatics and Telecommunications

Interdepartmental Graduate Program:

Science, Technology, Society—Science and Technology Studies

MSc Thesis

"Remaking the World into a CAD Design: Replacing Natural Complexity with Technological Simplicity"

Filippos Lymperopoulos-Bountalis

Registration Number:

Thesis Advisory Committee:

Stavros Ioannidis, Assistant Professor (Advisor)

Aristotle Tympas, Professor (Member)

Manolis Simos, Post-doctoral Researcher (Member)

Athens, 2024

Table of Contents

Acknowledgements

A big thank you to Professor Tympas for his unimaginable patience and understanding. I also want to thank Benjamin Moshe for his feedback on earlier versions of this work. Your support has been invaluable. I also want to thank Maura Dykstra and Tracy Dennison for teaching me how to ask questions and for standing by me in my first steps as an academic. More than anyone I should thank my parents for supporting me throughout.

Abstract

A dipole like technology-nature is commonplace in everyday discourse, but as with most such dipoles it has come under heavy criticism in professional philosophy and related fields. In this thesis, I will propose a particular way of constructing such a dipole and suggest some reasons why I find it useful to do so in this particular way. Specifically, technology in this case will mostly be characterized by purposeful design, and – at least ideally – simple geometries, orthogonality, reductionism, standardization and insulated objects with impermeable boundaries, while nature will be characterized by no purpose in design, emergence, and no ideality; rather, diversity, complexity, deviance from the norm, and semi-permeable boundaries will be recognized as functional necessities in this realm. Based on this distinction, I will also suggest that typically scientists study objects with the characteristics associated with technology in this dipole and even when seeking to study objects of the 'natural world' and formulate 'laws of nature' they will do their best to replace nature with an object of study that has these qualities which make it more amenable to mathematical description and predictable behavior. I will also note 'practical' aspects of these characteristics of technology and scientific activity having to do with assembly line production, discipline, and other aspects of modernity and capitalism. Finally, I wish to suggest that living in environments almost entirely reshaped by this technoscientific normality has in turn reshaped our ways of perceiving nature and the part of it that is humanity.

Introduction

After a long day at work, or on one of your days off, tired of seeing concrete all around, you take your car to the outskirts of the city or simply walk to the green space closest to where you are. Ahh, finally! Nature!

Figure 0. Finally, Nature!

As you're walking through the trees, you notice something weird. Or perhaps you don't notice it. You've grown so accustomed to it that you never really thought about it all that much. But, now, having read this thesis, you do! As you walk through the trees, there's a weird pattern, almost like an optical illusion: every couple of steps the trees overlap and you can see through the entire 'forest' at some angles, and it all looks a little too symmetrical and tidy. You squat down, bring your head almost to ground level; it's even more noticeable there, at the base of the trees: they all line up a little too well. "That's not a forest!" you scream (perhaps internally), "that's a plantation! Another damn military parade made of trees!"

From a layman's perspective it is hard to see a collection of trees as anything other than 'Nature.' And yet, there is something extremely unnatural about this sort of plantation, a collection of trees usually of the same species and age, arranged in straight lines with equal spacing between them. They could be water bottles in a warehouse or supermarket shelf, tiles on a floor, soldiers on a parade, or students' desks in a classroom, but plants simply don't grow that way.

There is a large bibliography in the philosophy of science and science studies-related fields problematizing the very use of concepts like 'Nature' and '(un)natural' (Latour, 1987; Daston & Park, 1998; Descola, 2014; Daston, 2019). I do not wish to disregard that scholarship and simply return to some tired binary trope of good 'Nature' and bad 'Technology.' However, living in a time of ecological collapse brought about by industrialized societies, a collapse which many prominent voices claim can only be diagnosed through scientific means and should be addressed with technological approaches, (UN Climate Change, 2019; Gates, 2021) it is hard not to wonder if there is not something to be gained by examining the guiding principles of these 'unnatural' arrangements and how they compare to 'natural' entities. It is hard not to notice the increase in 'unnatural' arrangements in our surroundings, even when entities typically regarded as 'natural,' like forests, are involved. And it is hard for STS scholars not to ask how cultural and scientific factors interweave in this subject: how our cultural environments aid in the proliferation of such arrangements and how the ubiquity of those arrangements in turn makes the principles that underlie them not only more culturally widespread but even goes to the point of naturalizing them.

There are other concepts one can use instead of 'Nature' and 'Technology.' For example, James C. Scott, in *Two Cheers for Anarchism*, speaks of 'vernacular order' and 'official order,' or one might choose to call one set of principles 'bottom-up' and the other 'top-down.' These terms might be more appealing to some, and they may in some ways be more accurate. Given that this is a work in STS and that I wish to make some remarks regarding scientists' appeal to 'Nature' (as for example in the phrase 'laws of Nature'), I will for now stick with the terms 'Nature' and 'Technology,' recognizing of course that they also have serious shortcomings.

I will not set out definitions for the two terms of the binary – 'Nature' and 'Technology' – at the start but slowly construct them as the text goes on. I see this text less as a complete description and more as a partial suggestion that can be expanded on. The various traits I will present are in many ways connected: even though I will present them somewhat separately they form a conceptual whole in the sense that it would be hard to imagine one of the traits being reversed and the rest staying the same. If one wanted to choose a central trait for each of the two terms of the binary it would probably be complexity for the first term, 'Nature' (or 'vernacular order'), and simplicity for the second term, 'Technology' (or 'official order'), but a more extensive analysis is required to get a good picture of the two opposing sets of principles.

Orthonormality and Uniformity VS Variety

It is probably easiest to begin with geometry. I will present this starting from the simplistic Nature-Technology division, but it will soon be evident that this effort undermines that very division. On the one hand, then, we have natural objects with the characteristics associated with Nature in this thesis. An array of examples is seen in figure 1 below:

Figure 1. Natural objects with the characteristics of Nature

Juxtaposed to this, we can have technological objects with the characteristics associated with Technology in this essay. In figure 2, you can see screen pixels and concrete buildings:

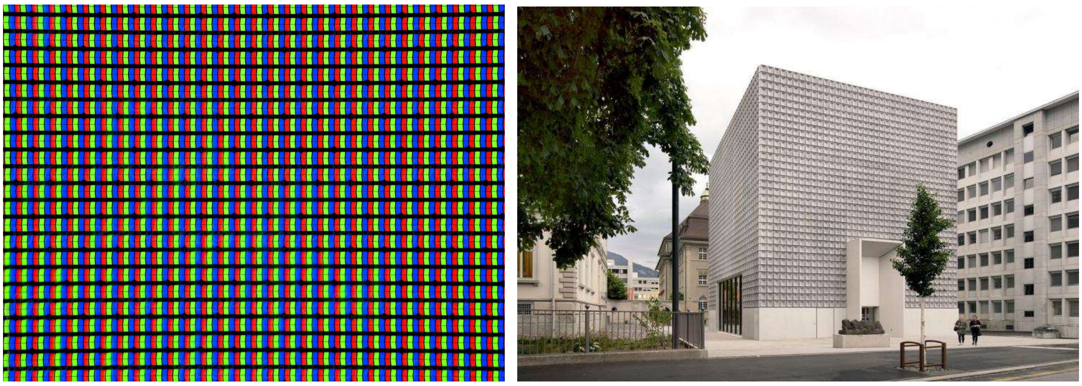

Figure 2. Technological objects with the characteristics of Technology

In both cases, we see that our objects are made up of smaller building blocks. What differs is that in figure 2 those building blocks are ideally identical and arranged in space in a uniform way with straight lines and right angles being dominant, while in figure 1 there is variety in shape, size, and positioning regarding the building blocks and the resulting geometries are not typically those of straight lines or right angles. Furthermore, the underlying building blocks are conceptually incredibly simple in the case of Technology, while, in the case of Nature, layer after layer displays the properties of variance and conceptual complexity.

Having looked at natural objects with the characteristics of Nature and technological objects with the characteristics of Technology, we can begin to complicate the picture by posing the associated questions of natural objects with the characteristics of Technology and technological objects with the characteristics of Nature. This undermines the Nature-Technology distinction as an ontological one and re-institutes it as a conceptual one.

The modern world is increasingly populated with natural objects arranged in a uniform way in straight lines and right angles and with a strong preference for maximizing homogeneity, i.e. with the characteristics associated with Technology, as shown in figure 3.

Figure 3. Natural objects with the characteristics of Technology

Technological objects with the characteristics of Nature are not entirely absent, but in the vast majority of cases they are the exception rather than the rule. A modern city may have a handful of landmark buildings made in the style of biomimicry (see figure 4) or in some other way deviating from the characteristics of Technology, but the vast majority of its buildings will be like those of figure 2. Similarly for the objects found in a typical house, workplace, store, etc.

Figure 4. Technological objects with the characteristics of Nature

There is a very simple explanation for this: capitalism. Assembly-line production and cost-minimization in the production process go hand-in-hand with simplicity, uniformity, and straight lines. There is also another more political reason why we observe the rise of uniformity and grid-like arrangement in modern society: discipline. As Michel Foucault writes in *Discipline and Punish*, this sort of arrangement is more amenable to supervision, classification, and correction. (Foucault, 1979, p. 145)

One more connection we can make with this proliferation of simplicity and homogeneity has to do with modern science. I will return to this in more detail later on but it should not be that controversial of a claim that knowledge of higher certainty goes together with objects of more simplicity. To put it simply, the more complicated you accept something to be, the harder it becomes to know it in an absolute and predictable way as is the ideal of Newtonian science. Homogeneity is also connected with the practical locus of modern science: experimental science based on replication. In one direction, advances in science allow for a more accurate manufacturing process with more uniform outcomes but, more importantly for us, in the other direction too, identical objects are a prerequisite in order to perform ideally identical experiments again and again.

Tied to the issues of production and science is also that of design: both more traditional tools of design like rulers and compasses, and more modern ones like computer-aided design (CAD) are more amenable to the use of straight lines (and circles), flat surface design, and, especially in the case of CAD, replication of identical building blocks.

All of these reasons go together and form positive feedback loops and they are also supplemented by a further cultural reason: habit and inertia. Once enough of the world is populated by these principles, it becomes easy for new designs to default to these same principles and, in many cases, it also becomes more difficult to create anything that does not follow these principles: in a world of irregular shapes, the remaining space to be filled and surfaces to make contact with are also irregular; in a world of straight lines, flat surfaces, and right angles, the remaining space and surfaces to attach to are also straight, flat, and orthogonal.

Adding 'Science' to the Picture

A critique of technological matters without an accompanying critique of matters scientific is a job half-done. Even worse, in a world that still largely accepts the view of science as neutral and technologies as the various possible less-neutral applications, such a critique risks appearing as a critique of circumstances and not of essence, as if with a few minor tweaks one could produce different technological applications, leaving the rest of the social system unchanged. For this reason I wish to delve more deeply into the connections between modern science and these principles that I have juxtaposed under the banners of 'Technology' and 'Nature.' I believe this to be crucial for a proper de-naturalization of the entities dealt with in this critique, which in some sense is the essence of critique in general.

There is a large bibliography dealing with the question of what exactly is 'modern science:' when it begins, when it ends (if we believe there is an important demarcation to draw at some point after its beginning), and what are its characteristics (Poincaré, 1905; Heisenberg, 1958; Feyerabend, 1993; Kuhn, 1996; Shapin, 1996; Foucault, 2002; Dear, 2012; Forman, 2012; Golinski, 2012). For the purpose of this essay, I will follow a rather typical definition for the beginning of modern science with Francis Bacon and Isaac Newton as the most central figures, insist on a significant shift or break in the 20th century with the repeated refutations of traditional 'Newtonian' science arising from within science itself (not only strong refutations as with the theory of relativity and quantum mechanics but also softer critiques such as the so-called 'science of ecology'), and focus not only on the theories and objects with which modern science deals, but also on its methodology, paying particular attention to the issue of experiments not only from a theoretical methodological perspective but also in its practical necessities and real conditions including the particular space of the laboratory. The approach for studying science in this essay is at once historical, anthropological, and one of literary criticism.

There is hardly any need to make an argument for the fact that the roots of modern science lie in texts and knowledge-making activities that study and attempt to make sense of Nature. This most obvious of facts is reflected in the language used to label these activities: 'physics,' the queen of the sciences, is named after the Greek word for Nature, 'Physis,' and many of the most prestigious scientific texts place themselves under the banner of 'natural philosophy,' including perhaps the most fundamental book in the history of modern science: Newton's *Philosophiæ Naturalis Principia Mathematica,* translated as *Mathematical Principles of Natural Philosophy*, where he sets out his famous laws of motion. To this day, we continue to call scientific principles 'natural laws.' And yet, if we examine modern science, from the way it is presented in school textbooks and news media to the activities carried out by many of those who appeal to the label of 'science' do we see the traits we associated with Nature like diversity and layers upon layers of complexity or do we see the characteristics of Technology: simple geometries, orthogonality, reductionism, and standardization?

‘The Environment’

Before going further I think I should introduce one final concept related to this issue of modern science and the study of Nature: the concept of ‘the environment.’[1] There is an interesting note to be made that ‘environment’ in popular, non-technical language is typically taken to mean ‘natural environment,’ i.e. nature, but I will leave that aside for now and focus more on how the technical concept is used in the physical sciences and in the associated way that a more broad notion of ‘environmental’ is correlated to the methodology of modern science.

‘The Environment’ as a Technical Concept in Science

‘The environment’ is not an ontological concept (what something *is*, by itself, in itself), but a relational term (what something is *relative to something else*). Something is typically referred to as part of the environment relative to something else which is the main object being considered: a blade of grass is part of a dog’s environment or the air is part of a cannonball’s environment, but, equally, that same dog is part of the blade’s environment.

In Nature, and at least in principle in the life sciences, ‘the environment’ and the entities that are grouped under that label play a constitutive role in defining what the main object (whose environment they make up) is and how it functions, and they must necessarily be included in a meaningful study and conceptualization of said object. One can hardly imagine an apple tree without the soil that surrounds its roots and supports it and which contains so many important nutrients for the tree, as does the air around it, or without the sun that feeds it sunlight, or without the insects that pollinate it, but also the insects and animals that feed off of it and the ones that antagonize them protecting the tree as a result, or the countless micro-organisms it has co-evolved with over millennia. And one can hardly imagine a meaningful description of that tree as a living organism that excludes those aspects of its ‘environment.’

In the case of the physical sciences, however, in the cases where one deals with objects one does not treat as living, and in some other cases we will explore soon, not only do the objects function without the need for the entities that make up their ‘environment,’ not only can one conceptualize them without caring about such peripheral concerns, but in fact one tries precisely to eliminate most if not all environmental factors in order for the object to function ideally and in order for it to be known in the way commonly recognized as most accurate. In these cases, ‘the environment’ functions as a term of exclusion, under which one collects all the pesky annoyances and complexities of the real world which one wishes to exorcize in order to obtain their perfectly functioning object.

Methodologically too this is how modern science typically functions. The most reliable way to study a correlation between two things is to keep everything else constant, then vary one and observe the other. And the easiest way to keep things constant is to exclude them altogether. In seeking to study most things, but also to construct them, one then begins with

[1] For a recent work in the history of science analyzing various meanings of ‘environment’ and their histories see Benson’s *Surroundings: A History of Environments and Environmentalisms* (2020).

the simplest building block, in a perfectly isolated environment, and, if possible and necessary, one can then begin to reintroduce some complicating factors, one at a time and very carefully, perhaps even removing one before introducing another. So, when a student begins to learn Newton's laws, they are presented with the case of 'free fall.' Free in what sense? Free from the influence of any environmental factors, an object falling in nothing. In time, perhaps a simplified version of air resistance may be added or a simplified version of an electromagnetic field, but in general, one studies the falling object in isolation and in that way and only in that way can one study it accurately. Even in moving from Newtonian physics to quantum mechanics the student once again begins with an object in a sea of nothingness: this time the 'particle in a box.' Here once again one may eventually add an energy barrier of some sort, a well, or some other complication, but the environment is a concept of exclusion, and methodologically the situation is practically opposite of the case of the apple tree described above. It is interesting to note at this point that this does not apply merely to the physical sciences, but once recognized can be observed in other fields too. For example the concept of 'externalities' functions in economics in much the same way. Just as the object-environment creates an inside which concentrates all matters of concern and an outside where one relegates what one wants to ideally ignore and practically at least simplify, so the concept of 'externalities' implies the same inside-outside division where once again what has been left outside is to some degree brought back into the arithmetic in an incredibly simplified form after being excluded in the initial modelling of the system.

This methodological approach is not only what one finds in theoretical instruction but also in experimental practice. The inaugurating experiment of modern science is Robert Boyle's air-pump by which he creates a vacuum, an empty space, a nothingness of an environment, an ideal space for the countless experiments which are to follow. As Shapin and Schaffer write in their famous book exploring the origins of experimental science: "The "vacuum" of his exhausted receiver was thus *not an experiment but a space in which to do experiments* and generate matters of fact without falling into futile metaphysical dispute."(Shapin & Schaffer, 2011, p. 46, emphasis added). And, indeed, Boyle publishes not one experiment but a set of experiments, the first one being the creation of a vacuum in the air-pump and the rest all carried out inside the vacuum of that air-pump (see figure 5). From its birth, then, experimental science deviates from that concept of natural philosophy, being instead carried out in an isolated artificial space where the 'environmental' is painstakingly excluded. Up until our days, laboratories, the space where most science takes place are painstakingly isolated, sterilized, and every attempt is made to keep the experimental set-up separate in each case from the interference of environmental factors.

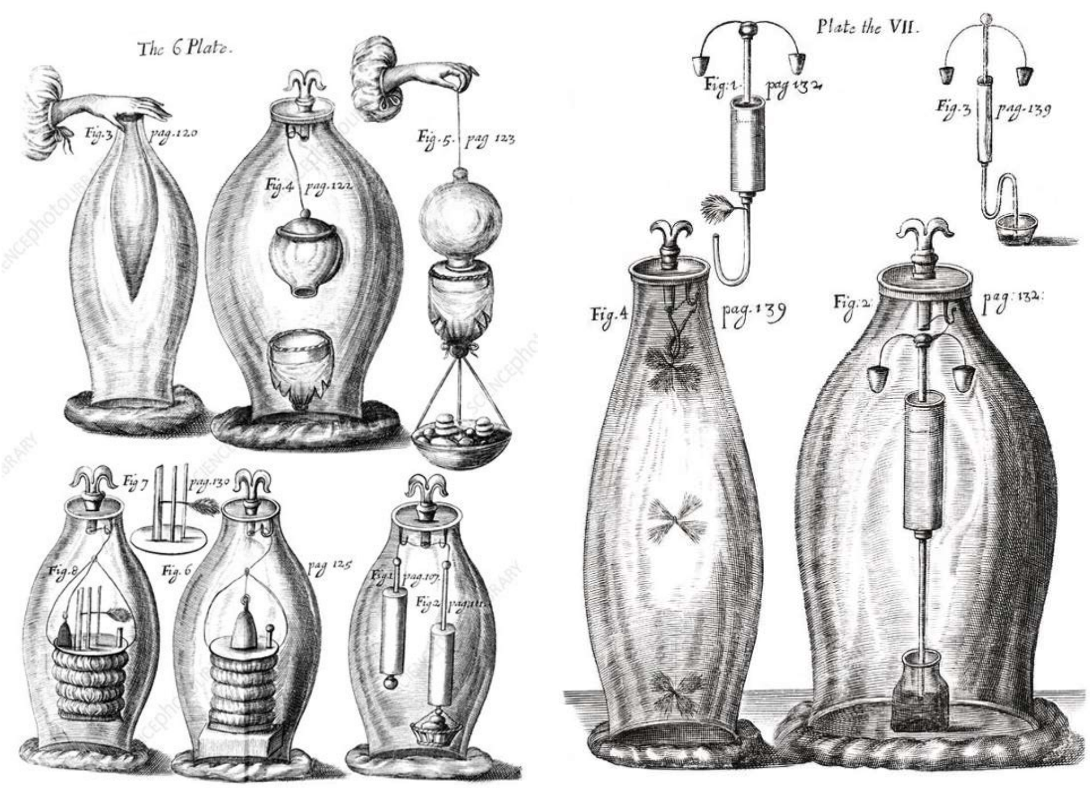

Figure 5. Boyle's Experiments in the Air-pump's Vacuum

All this is also in line with the principle of replication. Anyone can do one experiment, but for an experiment to be accepted, the same experiment has to be carried out again and again in different laboratories around the world.[2] If one wants to use an experimental set-up as a way of convincing others, one has to be able to create identical copies of that set-up in different places and different times, such that the experiment can be reproduced identically. This, of course, is a tremendous challenge. In fact, if one wants to replicate a set-up of billions upon billions of particles, an entirely identical environment, this is practically impossible. The project of experimental science was thus faced with a tremendous problem, that nothing could be exactly replicated across time and space, so nothing could form the basis of modern experimental science. To this problem the vacuum created in Boyle's air-pump provided an ingenious solution. If nothing could be exactly replicated across time and space, *nothing* would indeed be the basis of modern science. Every experiment would be conducted in *nothing*, in empty space, the one thing that could be reliably replicated across time and space.

[2] In reality, science as a social activity is also affected by status and cost, so a number of experiments are accepted without replication because it would simply be too costly (either economically or in terms of reputation) to doubt their validity as long as their outcomes do not differ in any significant way from what is expected. To establish ground-breaking discoveries though, and to establish the experimental method as *the* method for obtaining true knowledge replication has been crucial.

Different Relations to 'Environment' in Our Two Categories

This difference in the relation to 'environment', in the way one entity relates to the other entities around it, carries over into our bipartite division in two ways.

First, we see that in the case of Nature the entities are separated from their environment with semi-permeable boundary layers, and that this is necessary for them to perform their functions. Our skin needs to be able to breathe and sweat. Plants also absorb and release water, sugars and other chemicals through the boundary layer that separates them from their environment. At a lower level, cell also have semi-permeable membranes to separate the inside from the outside and this semi-permeability is a principle of their proper functioning. One can also look at larger-scale 'objects' like the soil which also contains pores of different sizes which are necessary for the organisms that inhabit it.

Opposed to this we observe ideally perfect insulation as a guiding principle in Technological artifacts. From fridges to all sorts of electronic devices in their cases, down to cables, themselves, up to houses and cars, down to simple bottles of water, and even to tiny transistors, there is a consistent effort to maximize the degree to which the inside is perfectly separated from the outside. One may in some cases wish to have optical transparency, but as a matter of principle in Technological artifacts we observe a drive to insulate from sound, heat exchange, air, water, etc. The standard is perfect insulation and its accompanying opposite if perfect, flawless, lossless transmission, but semi-permeability is a rare target in Technological design.

There is a tentative connection to be made between this issue of insulation and that of the passage of time: the passage of time is in a very fundamental sense connected with interaction between one entity and another, it is basically undefinable for an entity that is not made up of constituent parts that would interact with one another and which does not interact with any other entities. Living beings (and their constituent entities and resulting assemblages) are entities where process is key and the passage of time is a central part of their functioning, they are born, grow, and eventually decompose, giving rise to always-shifting biotic communities. Technological artifacts on the other hand are typically imagined as ideally timeless objects, unchanged and unaffected by the passage of time: machines would ideally not rust, their glass parts would remain unchanged forever, and so on. Packaged food, too, would ideally never spoil, by never coming into contact with anything that it would interact with. The drive for insulation is to some degree an effort to slow down or even completely freeze the aging of what is insulated, to keep at bay the inexorable passage of time. It can also however be connected to our current environmental crisis: one only has to realize what percentage of slow-to-decompose waste is made up of single-use packaging: typically cheap plastic used to insulate not only food but basically every single product sold these days. This lens of insulation allows us to re-examine various other aspects of our environment. For example, the urban environment is characterized in the last century by an almost ubiquitous covering up of the ground with concrete. This too is an effort in some sense to insulate and make timeless. Exposed ground gets quickly covered with vegetation which changes not only the surface but whose roots also undermine the foundations of buildings. And there are many more threats to the eternal order of urban society that an exposed ground is vulnerable to from burrowing critters to micro-organisms. Concrete insulates, or perhaps suffocates, the ground of our urban environment allowing the infrastructure we install to last so much longer than it would were the ground to be exposed. At the same time, it renders the urban environment practically uninhabitable for most life-forms that used to exist in that area before urban development took place. One could even draw analogies between these features of the urban environment and the laboratory environment, noting the similarities between the sterilized universal environment of a typically coastal, typically sea-level, typically concrete-covered, typically grid-like arranged modern city and the sterilized universal environment of the scientists' laboratory, both of them produced in almost identical copies around the world their homogeneity serving similarly the benefits of frictionless capitalist production on a global scale (and of a homogenized global culture) and of self-coherent globally-applicable knowledge.

The second difference in the relation to 'environment' is the issue of adaptation. In the case of Nature, it is the organism (or cell, ecosystem, etc.) that must adapt to its environment, while in the case of Technology, the environment is reshaped to be more amenable to the artifacts' ideal conditions. These are of course not absolute. Many organisms do to some extent reshape the world around them to their convenience and in some cases technological artifacts will be adapted to certain particular circumstances, but, as a matter of principle, the prevalence we observe quantitatively and qualitatively is that in Nature the environment is taken more or less as a given with adaptations made as necessary by the entities that inhabit it, while in the case of Technology an ideal product is designed and then the environment is reshaped in order to serve it, an animal's feet will change to best fit the ground it lives on while roads will be laid out to best fit the locomotion of ideally designed vehicles. For a more thorough account of this difference see Scott's text in the Appendix.

Which of Our Two Categories Does Science Describe?

We can close here this rather long parenthesis regarding the concept of 'the environment' and return to the previous considerations regarding the kind of knowledge provided by modern science and the objects that it studies – to put it simply: does modern science provide a description of Nature as was initially the expectation or are there parts that are left out, perhaps the ones most deserving of this label of Nature, the ones most characterized by the traits of complexity, variety, life?

What I wish to suggest is that there is a sleight of hand at play. To put it in terms of the four figures in the beginning of this text: The initial drive to develop modern science and the continued belief in its capabilities to a non-negligible extent depend on the claim that it provides descriptions of the objects of figure 1; instead what we see historically is that the incredible success related to the scientific revolution is mostly to do with a shift of attention to objects like those in figure 2 (clocks, pendula, steel beams, cannonballs, computer screens, etc.); to the extent that modern science appears to deal with natural objects what is meant in the vast majority of cases is something like what appears in figure 3, homogenized and disciplined substitutes of what used to pass for Nature. There is not much point in speaking of figure 4 since the more such objects differ from those of figure 2 the more their realization is still in the realm of imagination.

The Beginnings of Modern Science

This sleight of hand, hidden in plain sight, can be traced at least as far back as Francis Bacon, the so-called 'father of modern science,' who suggests "Why should we not divide natural philosophy into two parts, the mine and the furnace?" As Carolyn Merchant writes in *The Death of Nature* with reference to Bacon:

> Miners and smiths should become the model for the new class of natural philosophers who would interrogate and alter nature. They had developed the two most important methods of wresting nature's secrets from her, "the one searching into the bowels of nature, the other shaping nature as on an anvil" (1990, p. 171).

The mine is not that far removed from a traditional natural environment, lacking in charismatic lifeforms like mammals and trees, but still made up of soil, a complex mix of minerals, water, microorganisms, earthworms and so much more. It is however ideally and continuously transformed into a two-component system of inert structurally-necessary substrate and valuable mineral to be extracted, anything else potentially threatening the stability of the mine. The smith's furnace of course already has the characteristics associated with modern technology in this essay: a sterilized space of geometrical simplicity ideally made of a homogeneous material, typically metal with its atoms imagined arranged in an ideal orthonormal lattice.

Let us then examine the great successes of the scientific revolution. Newton, in his *Principia*, combines under one system of laws the behavior of heavenly bodies and that of everyday objects on Earth. That is the greatest success of the scientific revolution: universal laws of motion. What kind of objects do Newton's laws focus on and what kind of knowledge do they give us about them?

In the case of the heavenly bodies, Newton's laws certainly deal with objects of great complexity. They do not however deal with them as such. Newton, in his *Principia*, does not seek to explain what goes on in the interior of a star, or to explain the evolution of the sun's spots and storms, or anything else that would capture the heavenly bodies in their complexity. Instead, those bodies are treated as spheres, or even point particles, and all Newton is concerned with is their position and velocity as they travel through empty space. Newton has found the one instance in Nature that can provide a good approximation for the modern scientist's ideal environment, empty space, and he makes the most out of it.

Back on Earth, the laws of mechanics once again deal with inanimate and simplified objects: steel balls, smooth surfaces, gears, springs, and so on. Even the apple that falls on Newton's head might as well be a steel ball; his laws deal not with its appleness at all, they tell us nothing regarding its smell, its ripeness, its interactions with other living organisms, and so on. And the extent to which the laws can be reliably applied increases as one moves closer to the laboratory and the vacuum the scientists wish to create inside it. The acceleration of gravity is a constant for all objects: a feather and a steel ball fall at the same rate, but only in an environment free of air. The effects of air (or any other surrounding medium for that matter) on the motion of an object are a huge challenge for Newtonian mechanics so, whenever possible the air is removed, and when it is not possible the objects are chosen to be dense spheres, not only for the simplicity of their mass distribution but because that makes it easiest to consider air resistance to be negligible.

Remarks of Prominent Scientists towards the End of Modern Science

Such observations regarding both the crucial nature of isolating the object to be studied from its environment and of the shift away from what was traditionally understood to be natural objects about which knowledge was sought towards technological artifacts about which knowledge could be formulated in a satisfactorily accurate manner can also be found expressed by one of the great scientists of the 20th century: Werner Heisenberg. In his *The Physicists' Conception of Nature*, Heisenberg writes: "As scientists delved more deeply into the details of natural processes they realized, as in fact Galileo had been the first to do, that individual natural processes can be *isolated from their context* in order to be described and explained mathematically" (1958, p. 8, emphasis added). And a couple of pages later:

Changes in the Meaning of the Word 'Nature'

> Inasmuch as this kind of science was successful, it spread beyond the realm of daily experience into distant realms of nature, which could only be opened up properly by means of techniques which arose out of the development of science itself. Even in Newton's case, the decisive step had been his realization that the

> same laws of mechanics which governed the fall of a stone determined the motion of the moon about the earth; in other words, they could also be applied on a cosmic scale. In the period that followed, science began its victorious march on a broad front even in those distant realms of nature which could only be entered through technology, *i.e.*, by means of more or less complicated instruments. Astronomy, making use of ever better telescopes, conquered ever wider cosmic spaces. From the behavior of matter during chemical changes, chemistry tried to fathom processes on the atomic scale. Experiments with the induction machine and the Voltaic cell provide the first common knowledge of electrical phenomena not yet understood. *Thus, there took place a slow change in the significance of 'nature' as a subject for investigation by science. It became a collective concept for all those realms of experience into which man could penetrate by means of science and technology, regardless of whether or not they appeared as 'nature' to his immediate perception. Even the phrase 'description of nature' lost more and more of its original significance of a living and meaningful account of nature.* Increasingly it became to mean the mathematical description of nature, i.e., an accurate and concise yet comprehensive collection of data about relations that hold in nature (1958, pp. 10–11, emphasis added).

Heisenberg does maintain the reference to 'nature' in the last sentence, but the description that has proceeded it does not really justify it, unless one adopts the use of 'nature' as a synonym for 'material world' in general. As is very common, perhaps even inevitable in formulations of such matters the referents of words (in this case focusing on 'nature') shifts from sentence to sentence, or even within a single sentence.

Reductionism VS Emergence

On the question of simplicity we can also find a number of scientists either asserting its necessity as an assumption or its truth as an objective fact. One of the most interesting texts is Henri Poincaré's *Science and Hypothesis*. In a section titled "The Unity of Nature" (I will return to the issue of unity briefly), Poincaré makes some remarks on what he calls "the unity and simplicity of Nature":

> As for the second point, that is not so clear. It is not certain that Nature is simple. Can we without danger act as if she were?
>
> There was a time when the simplicity of Mariotte's law was an argument in favour of its accuracy: when Fresnel himself, after having said in a conversation with Laplace that Nature cares naught for analytical difficulties, was compelled to explain his words so as not to give offence to current opinion. *Nowadays, ideas have changed considerably; but those who do not believe that natural laws must be simple, are still often obliged to act as if they did believe it. They cannot entirely dispense with this necessity without making all generalisation, and therefore all science, impossible. It is clear that any fact can be generalised in an infinite number of ways, and it is a question of choice. The choice can only be guided by considerations of simplicity.* Let us take the most ordinary case, that of interpolation. We draw a continuous line as regularly as possible between the points given by observation. Why do we avoid angular points and inflexions that are too sharp? Why do we not make our curve describe the most capricious zigzags? It is because we know beforehand, or think we know, that the law we have to express cannot be so complicated as all that. […]
>
> If we study the history of science we see produced two phenomena which are, so to speak, each the inverse of the other. Sometimes it is simplicity which is hidden under what is apparently complex; sometimes, on the contrary, it is simplicity which is apparent, and which conceals extremely complex realities. […]
>
> No doubt, if our means of investigation became more and more penetrating, we should discover the simple beneath the complex, and then the complex from the simple, and then again the simple beneath the complex, and so on, without ever being able to predict what the last term will be. *We must stop somewhere, and for science to be possible we must stop where we have found simplicity. That is the only ground on which we can erect the edifice of our generalisations.* But, this simplicity being only apparent, will the ground be solid enough? That is what we have now to discover.
>
> For this purpose let us see what part is played in our generalisations by the belief in simplicity. We have verified a simple law in a considerable number of particular cases. We refuse to admit that this coincidence, so often repeated, is a result of mere chance, and we conclude that the law must be true in the general case (1905, pp. 145–149, emphasis added).

As this is a philosophical text, intended for an audience of fellow scientists Poincaré is more honest than ideological: he does not proclaim that 'Nature,' out there, is in reality simple, he rather states that 'Nature,' the object of natural science, must by necessity be simple for science to be possible. On the other hand, Carl Sagan, in his famous science popularization TV series *Cosmos: A Personal Voyage* is addressing a lay audience in his role as an authority-scientist and, even though he admits the same methodological necessity, he does so in a way that posits simplicity as a feature of Nature, out there: "if we lived in an unpredictable world where things changed in random or complex ways we wouldn't be able to figure things out and there'd be no such thing as science"[3] ("Cosmos," 1980). What is implied, of course is that, since science exists, the world must be simple. And we return to our question: does modern science find a simple world and explain it, or does it replace the complex with the simple since it is only the simple that it can explain, and having explained the simple that now masquerades for the whole 'world' aims to suppress that in the place of the docile simple there once was and somewhere still remains something complex which will continue to evade it?

In a later section of *Science and Hypothesis*, Poincaré treats the issue of unity (which he again ties with simplicity) in much the same way: noting two opposing trends, making an overview of the history of scientific theories, and ending on a rather optimistic note as to which trend will win out in the end, a conclusion however significantly undermined by the fate that befell in the following decades the theories he bases his hopes on.

> *The Present State of Physics.* – Two opposite tendencies may be distinguished in the history of the development of physics. On the one hand, new relations are continually being discovered between objects which seemed destined to remain for ever unconnected; scattered facts cease to be strangers to each other and tend to be marshalled into an imposing synthesis. The march of science is towards unity and simplicity.
>
> On the other hand, new phenomena are continually being revealed; it will be long before they can be assigned their place sometimes it may happen that to find them a place a corner of the edifice must be demolished. In the same way, we are continually perceiving details ever more varied in the phenomena we know, where our crude senses used to be unable to detect any lack of unity. What we thought to be simple becomes complex, and the march of science seems to be towards diversity and complication. […]
>
> From this cursory exposition what can we conclude? Taking all things into account, we have approached the realisation of unity. This has not been done as quickly as was hoped fifty years ago, and the path predicted has not always been followed; but, on the whole, much ground has been gained. (Poincaré, 1905, pp. 172–173, 182)

More than a century later, a unified theory remains the dream for many physicists (at least certainly in the outward-facing image of the community towards the lay audience), a unified theory of course being only a mirror of a unified (and simple) nature. The issue of unity is connected to one element of our binary distinction that we have yet to elaborate on: reductionism vs emergence. To put it simply: in the reductionist perspective, in line with the principles associated with Technology, the object of interest can be divided into its constituent parts and an understanding of the whole is simply an addition of an

[3] 9:55-10:05 in episode 3

understanding of its parts. Opposed to this is the notion that the whole is more than the sum of its parts, i.e. that there are emergent properties in the behavior of the whole, that cannot be extrapolated from what can be observed for each part individually. It is common for those adopting the (Newtonian) physicists' conception of Nature to claim that the complex living organisms and ecosystems which still resist, will sooner or later be absorbed in the knowledge base of physical science and unproblematically reduced to physico-chemical mechanisms, completing a unified physics-centered, physics-reducible image of Nature. For example, the latest version of the SI Brochure, the document in which the fundamental units like the second and the meter are defined, notes towards the end of its definitions that: "There is a class of units for quantifying the biological activity of certain substances used in medical diagnosis and therapy that cannot *yet* be defined in terms of the units of the SI. This lack of definition is because the *mechanism* of the specific biological effect of these substances is not *yet* sufficiently well understood for it to be quantifiable in terms of physico-chemical parameters." (BIPM, 2019, p. 141, emphasis added)

There are many voices in the biological sciences putting forth a critique of reductionism. The field of ecology has carved out its particular niche in the academic ecosystem partly by stressing the importance of emergence as a guiding principle in the study of organisms and ecosystems as opposed to reductionist approaches. Relevant to our previous section, many ecologists have also stressed the importance of studying organisms in the field rather than extracting them and studying them in the sterilized environment of the laboratory.[4] A more recent example of taking a stand against reductionism in the biological sciences is that of Robert Sapolsky in his Stanford lecture series on behavioral biology, which to the best of my knowledge is the most-watched academic lecture series on Youtube at the time of writing.[5]

In fact, if one wants to find a critique of the short-comings of Newtonian mechanistic reductionism and an opposing support for emergence one does not even need to look further than physics; it is simply a matter of moving into 20th century physics and catching up with quantum mechanics. There is considerable literature supporting that quantum entanglement serves as proof of the existence and in fact ubiquity of emergent properties in nature.[6] Unfortunately, Newtonian physics monopolizes the levels of mandatory education and anyone who does not follow physics into university would believe that the doctrines of Newtonian mechanistic reductionism are still in line with the best theories in physics. For

[4] Despite this, with the increase in our ability to handle large amounts of data and the associated fad (as commonly happens with technological advances) to make use of this ability in every potential way, the field of ecology has experienced its own version of 'Nature' being replaced by technological artifacts as the object of study upon which new findings are based. In this case, an increasing number of studies in ecology involve the collection of organisms from the field, their subsequent conversion into data (typically by sequencing their DNA) and the carrying out of analysis on that data rather than the organisms themselves (Devictor & Bensaude-Vincent, 2016).

[5] Sapolsky in his famous *Human Behavioral Biology* lectures takes pretty much the opposite position from Poincaré, not so much normatively and methodologically (what we should do for science to be possible) but empirically/ontologically, i.e. that as far as we've studied 'Nature' (Sapolsky doesn't use the term, Poincaré does) there's complexity and variability at every level, "all the way down" (16:07-20:00 and then again starting at 1:21:00) (Stanford, 2011). The paper he refers to is (Sapolsky & Balt, 1996)

[6] See for example (Lewis, 2017) and the texts referenced in the first paragraph of this article.

mandatory education, it is as if the last century of physics never occurred.[7] In public discourse, quantum mechanics does occasionally come up, but even then it is usually in a very disappointing way for a philosopher or historian of science. This is not the place to go into this more deeply, but it is important to note that physicists themselves had to give up traditional reductionist approaches to their object of study once they started asking hard enough questions.

[7] On the outdated teaching of physics in primary and secondary education see among others (Gordon, 1984).

Ideality

Let us now turn to the last element of our distinction: that of ideality. Ideality refers us back to perhaps the most classical text in the history of philosophy: Plato's allegory of the cave in the *Republic*. There, Plato famously posits that the entities we interact with in our everyday life are but mere shadows of the true entities which are their ideal Forms. There is in this view the ideal Form of a Chair with all chairs we interact with in our everyday life being simply imperfect shadows inspired by the ideal Form of the Chair. Similarly, one could say that there is an ideal Form of a particular dog breed or plant species with all instantiations of it encountered in real life being imperfect shadows of that ideal Form. This is the sort of philosophy associated with an ontology which takes itself to be objectively true and not merely socially convenient, and this is the way biological taxonomy is often treated outside the narrow confines of professional discussions among taxonomists themselves or philosophers of biology.

As one moves towards physics and the experiments conducted in vacuum, as in the case of particle physics, one finds more and more this sort of philosophy in which the idealized theoretical abstraction (the ontology) comes to be more real than the empirical observables from whose observation it arose, from the periodic table to the equivalent tables for subatomic particles. Perhaps the philosophical culmination of this was the suggestion of the one-electron universe, i.e. that one could imagine the various electrons not merely as identical copies conforming to the standard of the Form of the Electron but as indeed being ontologically a single entity, one higher-dimensional Electron which intersects the fabric of space-time at various points which we interpret as the numerous electrons (or positrons in the case where it intersects it going in the opposite direction).

As one moves towards biology however this sort of strict objective ontology is replaced by a variety of different potential taxonomic practices and a recognition that this kind of knowledge too is socially constructed and bears the marks of the society that constructs it. Darwin, for example, in his *On the Origin of Species*, after spending a few pages discussing the potential for a definition of terms like "species" and "variety" concludes that:

> From these remarks it will be seen that I look at the term species as one arbitrarily given, for the sake of convenience, to a set of individuals closely resembling each other, and that it does not essentially differ from the term variety, which is given to less distinct and more fluctuating forms. The term variety, again, in comparison with mere individual differences, is also applied arbitrarily, for convenience's sake.(Darwin, 2008, p. 43) […] there is no infallible criterion by which to distinguish species and well-marked varieties. (2008, p. 46)
>
> Hence, in determining whether a form should be ranked as a species or a variety, the opinion of naturalists having sound judgment and wide experience seems the only guide to follow. We must, however, in many cases, decide by a majority of naturalists, for few well-marked and well-known varieties can be named which have not been ranked as species by at least some competent judges. (ibid., p. 39)

Darwin also provides what would today be called an externalist argument, that is to say an explanation of scientific activity that is affected by extra-scientific social factors, when he says: "I have been struck with the fact, that if any animal or plant in a state of nature be highly useful to man, or from any cause closely attract his attention, varieties of it will almost universally be found recorded. These varieties, moreover, will be often ranked by some authors as species." (ibid., p. 41) The qualitative leap from "individual differences" to "varieties" and "species" is thus not determined by attributes inherent in 'Nature' or 'the field of biology' but varies even among "competent judges" and is also affected by economic and cultural aspects of the societies which formulate the knowledge about these organisms.

Diversity is necessary in the scope of evolutionary biology. There must exist slightly different organisms so that some of them will have a higher and some a lower fitness for the changing environment in which they exist and over time different life forms will arise. If organisms were like the products of assembly line production or the particles of the physicists identical then a single stressor would be much more likely to wipe out the entire population. The products of mass production are not only ideally identical, but they indeed have a Form of which they are imperfect shadows and an undisputable ontological label: they are made according to a blueprint for a particular purpose. The standardized parts that come out of a factory do indeed have ideal dimensions and any deviation from those is not a factor aiding their survival as a species but a factor dooming the individual item to be discarded.[8] A new constructivist question joins the ones above: Is the Platonism of assembly line production a mirror of Platonism in 'Nature' or does the Platonism in the physical sciences which is taken to be a mirror of 'Nature' arise from the experience of a world increasingly populated by assembly-line-produced objects and as a result one in which that philosophy is increasingly naturalized?[9]

[8] This is all once again in ideality. One can of course imagine a faulty product coming out of the assembly line being the source of inspiration for a new useful object to be produced, and on the other hand a number of variant traits doom individual organisms to lower reproductive futures, but what I am mostly focused on here is a matter of principles and not of exceptions.

[9] The connection between assembly line production and the identical particles of physicists is noted by some prominent scientists as well. For example as Peter Dear relays, Maxwell makes some relevant remarks in the 19th century: "An article by Maxwell on the atom in the mid-1870s drew on related aspects of Victorian industrialism to make a natural-theological point. Following John Herschel, Maxwell observed that the absolute physical identity of all atoms of the same kind was like the identity of similar manufactured articles. Mass production (perhaps powered by steam engines) implied deliberative intelligence, and since atoms were morally the equivalent of identical factory products, they too must be the result of intelligent design. In 1802, William Paley's God had been a craftsman; now Maxwell's was a Victorian industrial manufacturer." (Dear, 2008, p. 140)

Synthesis and Human Nature

Putting it all together, we thus have a double sleight-of-hand: on one side we have scientists in their activities and theories repeatedly substituting the complex 'natural' with their simplifying idealizations, simple enough for scientific generalizations ('laws') to be possible with the promise that *eventually* these same laws will be demonstrated to hold for the complex 'natural,' while at the same time, in the real world, outside the confines of the scientists' laboratories and textbooks, the complex 'natural' is increasingly substituted by the simple technological which, manufactured in close connection with scientific laws and in an iterative process that keeps the two in agreement, serves as the proof that those generalizations do indeed describe the real world out there. We do indeed now know the principles that govern the world we live in, but is it because technoscience has advanced in its understanding of nature or because it has advanced in its replacement of it?

The success of the last few centuries may then have to be at least partly attributed to simply making the world more predictable. Cars are simpler and more predictable than horses. Assembly line production is simpler[10] and more predictable than 15th century artisan production. The sixth mass extinction will certainly make the study of the natural world a lot simpler given how fewer objects of study will remain. The animals we surround ourselves with are increasingly store-bought 'pure breeds,' the plants we put in our gardens and the ones we cultivate for food are also increasingly standardized with a drive for uniformity and predictable behavior. Even when something does not work as expected it is unlikely that the degree of our knowledge will come into question; the malfunctioning object can simply be discarded and replaced with one that will work, at least for long enough to keep our faith in the principles. We are not witnessing an increased understanding of the forest and the birds that sing in it, but its replacement by a factory with its own particularly monotonous singing.

In a similar vein we can examine not only the situation regarding non-human Nature, but also that of human nature: is our increased understanding of how humans function, both as individual organisms and as social beings, simply a result of superior methods of analysis and an increase in the effort expended to study humans or it is also the result of a replacement of a large variety of human forms to be studied by a rather homogeneous sample of mostly White, urban, modern humans? Is it possible that our attempts at a reflexive study of ourselves are plagued by these same issues: replacing humanity as a complex aspect of 'Nature' with its 'Technological' simplification of a modern, Western individual and mistaking the properties of that technological artifact for the properties of the plethora of beings it is substituting out of existence?

Over the twentieth century, social scientists designed a number of experiments to study the people around them and create scientific knowledge about human nature. Countless volunteers, most of them university students, attended these experiments. A simple example of such an experiment consists in giving the volunteer $10 and asking them to share any amount they wish with another unknown volunteer. This would measure how much they help others when no reward is foreseeable. In another experiment, the other volunteer would then give back any amount they wished which the researchers would double. This would measure

[10] Even if the number of moving parts has increased those parts are now standardized as opposed to the variety of unique and personalized objects and techniques involved in artisanal production.

how much they invest in trusting others, and on the second participant's side, how they respond to this trust. After running many variations of such experiments and amassing the data, economists, psychologists, and other social scientists were ready to proclaim that they had a scientific description of human behavior and by extension human nature. Then, some anthropologists decided to run the most popular experiments of this sort to see if they would replicate beyond the typical attendants of university experiments, out in the field, visiting many societies typically excluded from such studies. The result? Not only did the experiments on economic behavior return very different results but even studies on visual perception like the Müller-Lyer line illusion failed to replicate (Henrich et al., 2010).[11]

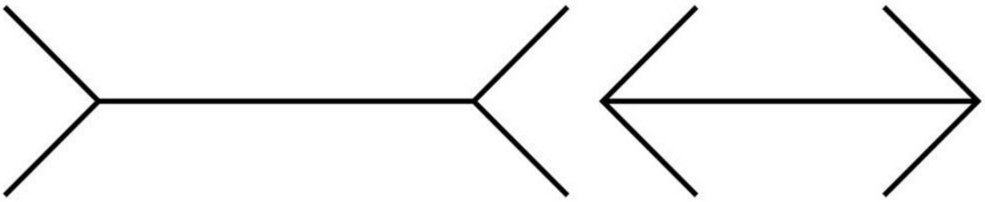

Figure 6. The Müller-Lyer optical illusion

In the Müller-Lyer test, participants are asked to compare the size of the two horizontal line segments.

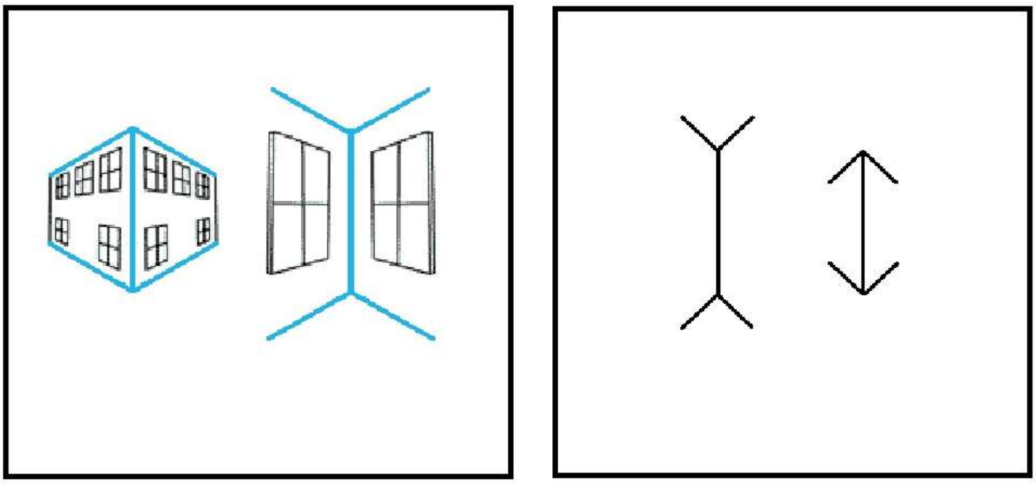

Figure 7. The Müller-Lyer optical illusion and urban architecture

Urban populations, used to interpreting the direction of the accompanying short lines at the ends as an indicator of depth, consistently judge one line to be longer, while non-urban ones tend to correctly declare the two lines to be equal. This scientific description of human nature which the behavioral scientists had been building throughout the 20th century and which many of them still support turns out to be little else than a description of the human culture of people living in an environment designed with straight rulers by straight rulers. More generally, as outlined in the 2010 review article by Joseph Henrich et al.:

[11] For the Müller-Lyer illusion in particular, see section 3.1 of Henrich et al.

Behavioral scientists routinely publish broad claims about human psychology and behavior in the world's top journals based on samples drawn entirely from Western, Educated, Industrialized, Rich, and Democratic (WEIRD) societies. Researchers – often implicitly – assume that either there is little variation across human populations, or that these "standard subjects" are as representative of the species as any other population. Are these assumptions justified? Here, our review of the comparative database from across the behavioral sciences suggests both that there is substantial variability in experimental results across populations and that WEIRD subjects are particularly unusual compared with the rest of the species – frequent outliers (2010, p. 61).

Conclusion

To sum up, over the preceding sections I set up a binary distinction whose terms I labeled ‘Nature’ and ‘Technology,’ not forgetting of course the trouble with using such words, and proceeded to outline some points of comparison between the two terms, some different principles of organization and conceptualization; one might even go as far as to call them two different forms of life, two different cultural models if one is willing to expand the concept of culture beyond the human. The choice of the labels was partly justified by bringing ‘Science’ into the picture, mostly and primarily on the side of ‘Technology,’ with some notable exceptions from the life sciences. What I argued is that the principal characteristics of scientific activities and scientific culture in general are typically in line with the principles associated with ‘Technology’ in the binary set up in this thesis, and that the socially-dominant image of science as a description of nature relies to a large extent on a double sleight of hand, a sleight of hand whose two aspects are tightly interwoven: on the one hand, the replacement in scientific experiments, instruction, etc. of complex ‘Nature’ with technological simplifications with the associated promise that eventually all the findings regarding the simplifications will be unproblematically extended to ‘Nature’ beyond any possible doubt, and, on the other hand the increasing replacement in the real world of ‘Nature’ by technological artifacts so that the everyday experience of those whose voice matters in global public discourse (typically middle-class-and-above, educated, White, male, etc. urban-dwellers) smoothly matches the technoscientific assemblages of artifacts and laws governing their behavior.

In a certain sense, the primary novelty of this thesis has been to argue with regard to technoscience what Horkheimer and Adorno argue with regard to the cinema in the following lines from their 1944 *The Dialectic of Enlightenment*:

> The familiar experience of the moviegoer, who perceives the street outside as a continuation of the film he has just left, because the film seeks strictly to reproduce the world of everyday perception, has become the guideline of production. The more densely and completely its techniques duplicate empirical objects, the more easily it creates the illusion that the world outside is a seamless extension of the one which has been revealed in the cinema (2002, p. 99).

Similarly for us today living in urban environments where the largest of architectural objects and the smallest of household items have been designed and manufactured according to technoscientific rules often with machines themselves designed and manufactured according to technoscientific rules, it is hard not to perceive the outside world as a seamless extension of the one we find in the laboratory, scientific textbooks, and technical manuals. We might marvel at the success of ‘smart city’ technologies and think little of how such technologies might be precisely suited to the urban rather than any other environment because both that environment and those technologies have been constructed according to the same set of technoscientific principles. We might look at monocultures planted equidistantly in straight lines – like a forest in Minecraft – and see only proof that the Moiré pattern is not a scientific abstraction but a natural occurrence in how trees grow. We might become convinced that the Muller-Lyer line illusion is human nature rather than another aspect of being embedded in this WEIRD technoscientific civilization. We might see the image (Fig.8) of the *Research on Research* feature in *Science* (Enserink, 2018) and think little of the analogy between the rectangular spaces in which the tiny scientists being studied find themselves and the rectangular ruler being held by the bigger scientist brooding over them; the Euclidean orthonormality and the lack of any potential complexity underneath the apparent simplicity are as pervasive and unnoticeable for us as water is for the fish that swim in it.

Figure 8. Reflections on Scientific Normality and Uniformity

The replacement of complex biotic communities with technological artifacts is obvious to anyone who has eyes to see, ears to listen, a nose to smell, and skin to touch the world around them. It is the naturalization of the different organizing principles that it is the effort of this piece to bring to the reader's attention and undermine, the associated cultural shifts from living in a world dominated by the principles of 'Technology,' and to highlight the potential connections one can draw to the climate catastrophe we are experiencing today and the larger environmental collapse it is a part of. This last point would have required a considerably larger piece to do it justice, but I hope at least some seeds have been planted in the minds of readers in this direction too.

Appendix

In-betweens: Fabric - Clothing

It is interesting to note a category of very common every-day objects that falls very definitively in-between the two terms (‘Nature’ and ‘Technology’): that of fabrics, and especially clothing. The existence of such objects does not undermine the usefulness of this framework as a way of approaching the world around us, it only undermines the mistaken perception of it as an ontological division rather than a conceptual framework.

Typically, modern clothing is made up of a thread criss-crossing itself or other threads in a grid-like rectangular pattern. Given however the elasticity of the thread and the effect of it usually being one string going up and down rather than multiple strings beginning and ending at the ends of the fabric, the fabric folds in three-dimensional space in ways that are atypical for a classical grid-like sheet object, like the grid wire used for fences. This is in part what makes fabrics so difficult to model in computer-generated graphics as in the case of video games. In addition to this feature, because clothes are not simply functional artifacts but also artistic objects, even though there is some standardization of sizes and dimensions, there is incredible variability in the actual shape of clothes (even t-shirts of the same size do not have the same shape) and it is rather atypical to find clothing with right angles or perfectly straight lines in its shape. What’s more, precisely because clothing functions as an extra skin on a living organism it is typically made along the principles of semi-permeable boundaries (fabric that ‘breathes’) rather than complete insulation of inside from outside. Clothing does however retain other features of ‘Technology:’ even though there is a large variety of designs, each design is typically produced in a significant number of ideally-identical copies and, of course, with an ideal Form, in mind.

Vernacular Order, Official Order

I have struggled for a while about what to do with Scott's text on vernacular and official order. It overlaps so extensively with my thesis material[12] even though it follows an entirely different organizational logic and order of presentation. The more standard approach would have probably been to chop it up into pieces and refer to it in the relevant sections of my text. I believe that would have made both texts worse. I could have also omitted it more or less entirely. It would make this thesis appear more original and do away with what some would call unnecessary repetition. I believe there is much to be gained in relaying it uninterrupted at the end of my piece. It is an opportunity for the reader to see the same material presented in a different way which I believe serves as a reinforcement of the arguments and makes the material more easily and thoroughly understood. The two pieces have some overlap but I think they work in very complementary ways rather than being repetitive.

> The industrial assembly line is, from this perspective, the replacement of vernacular, artisanal production by a division of labor in which only the designing engineer controls the whole labor process and the workers on the floor become substitutable "hands." It may, for some products, be more efficient than artisanal production, but there is no doubt that it always concentrates power over the work process in those who control the assembly line. The utopian management dream of perfect mechanical control was, however, unrealizable not just because trade unions intervened but also because each machine had its own particularities, and a worker who had a vernacular, local knowledge of *this* particular milling or stamping machine was valuable for that reason. Even on the line, vernacular knowledge was essential to successful production.
>
> Where the uniformity of the product is of great concern and where much of the work can be undertaken in a setting specifically constructed for that purpose, as in the building of Henry Ford's Model T or, for that matter, the construction of a Big Mac at a McDonald's, the degree of control can be impressive. The layout, down to the minutest detail at a McDonald's franchise, is calculated to maximize control over the materials and the work process *from the center*. That is, the district supervisor who arrives for an inspection with his handy clipboard can evaluate the franchise according to a protocol that has been engineered into the design itself. The coolers are uniform and their location is prescribed. The same goes for the deep fryers, the grills, the protocol for their cleaning and maintenance, the paper wrappers, etc., etc. The platonic form of the perfect McDonald's franchise and the perfect Big Mac has been dreamed up at central headquarters and engineered into the architecture, layout, and training so that the clipboard scoring can be used to judge how close it has come to the ideal. In its immanent logic, Fordist production and the McDonald's module is, as E. F. Schumacher noted in 1973, "an offensive against the unpredictability, unpunctuality, general waywardness and cussedness of living nature, including man."

[12] The only part absent in Scott's account is that on the permeability of boundaries.

It is no exaggeration, I think, to view the past three centuries as the triumph of standardized, official landscapes of control and appropriation over vernacular order. That this triumph has come in tandem with the rise of large-scale hierarchical organizations, of which the state itself is only the most striking example, is entirely logical. The list of lost vernacular orders is potentially staggering. I venture here only the beginning of such a list and invite readers, if they have the appetite, to supplement it. National standard languages have replaced local tongues. Commoditized freehold land tenure has replaced complex local land-use practices, planned communities and neighborhoods have replaced older, unplanned communities and neighborhoods, and large factories and farms have replaced artisanal production and smallholder, mixed farming. Standard naming and identification practices have replaced innumerable local naming customs. National law has replaced local common law and tradition. Large schemes of irrigation and electricity supply have replaced locally adapted irrigation systems and fuel gathering. Landscapes relatively resistant to control and appropriation have been replaced with landscapes that facilitate hierarchical coordination.

FRAGMENT 7

The Resilience of the Vernacular

It is perfectly clear that large-scale modernist schemes of imperative coordination can, for certain purposes, be the most efficient, equitable, and satisfactory solution. Space exploration, the planning of vast transportation networks, airplane manufacture, and other necessarily large-scale endeavors may well require huge organizations minutely coordinated by a few experts. The control of epidemics or of pollution requires a center staffed by experts receiving and digesting standard information from hundreds of reporting units.

Where such schemes run into trouble, sometimes catastrophic trouble, is when they encounter a recalcitrant nature, the complexity of which they only poorly comprehend, or when they encounter a recalcitrant human nature, the complexity of which they also poorly comprehend.

The troubles that have plagued "scientific" forestry, invented in the German lands in the late eighteenth century, and some forms of plantation agriculture typify the encounter. Wanting to maximize revenue from the sale of firewood and lumber from domain forests, the originators of scientific forestry reasoned that, depending on the soil, either the Norway spruce or the Scotch pine would provide the maximum cubic meters of timber per hectare. To this end, they clear-cut mixed forests and planted a single species simultaneously and in straight rows (as with row crops). They aimed at a forest that was easy to inspect, could be felled at a given time, and would produce a uniform log from a standardized tree (the *Normalbaum*). For a while–nearly an entire century–it worked brilliantly. Then it faltered. It turned out that the first rotation had apparently profited from the accumulated soil capital of the mixed forest it had replaced without replenishment. The single-species forest was above all a veritable feast for the pests, rusts, scales, and blights that specialized in attacking the Scotch pine or the Norway spruce. A forest of trees all the same age was also far more susceptible to catastrophic storm and wind damage. In an effort to simplify the forest as a one-commodity machine, scientific forestry had radically reduced its diversity. The lack of tree species diversity was replicated at every level in this stripped-down forest: in the poverty of insect species, of birds, of mammals, of lichen, of mosses, of fungi, of flora in general. The planners had created a green desert, and nature had struck back. In little more than a century, the successors of those who had made scientific forestry famous in turn made the terms "forest death" (*Waldsterben*) and "restoration forestry" equally famous.

Henry Ford, bolstered by the success of the Model T and wealth beyond imagining, ran into much the same problem when he tried translating his success in building cars in factories to growing rubber trees in the tropics. He bought a tract of land roughly the size of Connecticut along a branch of the Amazon and set about creating Fordlandia. If successful, his plantation would have supplied enough latex to equip all his autos with tires for the foreseeable future. It proved an unmitigated disaster. In their natural habitat in the Amazon basin, rubber trees grow here and there among mixed stands of great diversity. They thrive amid this variety in part because they are far enough apart to minimize the buildup of diseases and pests that favor them in this, their native habitat. Transplanted to Southeast Asia by the Dutch and the British, rubber trees did relatively well in plantation stands precisely because they did not bring with them the full complement of pests and enemies. But concentrated as row crops in the Amazon, they succumbed in a few years to a variety of diseases and blights that even heroic and expensive efforts at triple grafting (one canopy stock grafted to another trunk stock, and both grafted to a different root stock) could not overcome.

In the contrived and man-made auto-assembly plant in River Rouge, built for a single purpose, the environment could, with difficulty, be mastered. In the Brazilian tropics, it could not. After millions had been invested, after innumerable changes in management and reformulated plans, after riots by the workforce, Henry Ford's adventure in Brazil was abandoned.

Henry Ford started with what his experts judged to be the best rubber tree and then tried to reshape the environment to suit it. Compare this logic to its mirror image: starting with the environmental givens and then selecting the cultivars that best fit a given niche. Customary practices of potato cultivation in the Andes represent a fine example of vernacular, artisanal farming. A high-altitude Andean potato farmer might cultivate as many as fifteen small parcels, some on a rotating basis. Each parcel is distinct in terms of its soil, altitude, orientation to sun and wind, moisture, slope, and history of cultivation. There is no "standard field." Choosing from among a large number of locally developed landraces, each with different and well-known characteristics, the farmer makes a series of prudent bets, planting anywhere from one cultivar to as many as a dozen in a single field. Each season is the occasion for a new round of trials, with last season's results in terms of yield, disease, prices, and response to changed plot conditions carefully weighed. These farms are market-oriented experiment stations with good yields, great adaptability, and reliability. At least as important, they are not merely producing crops; they are reproducing farmers and communities with plant-

> breeding skills, flexible strategies, ecological knowledge, and considerable self-confidence and autonomy.
>
> The logic of scientific extension agriculture in the Andes is analogous to Henry Ford's Amazonian plantations. It begins with the idea of an "ideal" potato, defined largely but not entirely in terms of yield. Plant scientists then set about breeding a genotype that will most closely approximate the desired characteristics. That genotype is grown in experimental plots to determine the conditions that best allow it to flourish. The main purpose of extension work, then, to retrofit the entire environment of the farmer's field so as to realize the potential of the new genotype. This may require the application of nitrogen fertilizer, herbicides, and pesticides, special field and soil preparation, irrigation, and the timing of cultivation (planting, watering, weeding, harvesting). As one might expect, each new "ideal" cultivar usually fails within three or four years as pests and diseases gain on it, to be replaced in turn with a newer ideal potato and the cycle begins again. To the degree that it succeeds, it turns the fields into standard fields and the farmers into standard farmers, just as Henry Ford standardized the work environment and workers in River Rouge. The assembly line and the monoculture plantation each require, as a condition of their existence, the subjugation of both the vernacular artisan and of the diverse, vernacular landscape (Scott, 2012, pp. 34–40).

After making similar comments regarding the design of cities Scott returns to the issue of agriculture:

> Like the city official peering down at the architect's proposed model of a new development site, we are all prone to the error of equating visual order with working order and visual complexity with disorder. It is a natural and, I believe, grave mistake, and one strongly associated with modernism. How dubious such an association is requires but a moment's reflection. Does it follow that more learning is taking place in a classroom with uniformed students seated at desks arranged in neat rows than in a classroom with un-uniformed students sitting on the floor or around a table? The great critic of modern urban planning, Jane Jacobs, warned that the intricate complexity of a successful mixed-use neighborhood was not, as the aesthetic of many urban planners supposed, a representation of chaos and disorder. It was, though unplanned, a highly elaborated and resilient form of order. The apparent disorder of leaves falling in the autumn, of the entrails of a rabbit, of the interior of a jet engine, of the city desk of a major newspaper is not disorder at all but rather an intricate functional order. Once its logic and purpose are grasped, it actually looks different and reflects the order of its function.
>
> Take the design of field crops and gardens. The tendency of modern "scientific" agriculture has favored large, capital-intensive fields, with a single crop, often a hybrid or clone for maximum uniformity, grown in straight rows for easy tillage and machine harvesting. The use of fertilizers, irrigation, pesticides, and herbicides serves to make the field conditions as suitable to the single cultivar and as uniform as possible. It is a generic module of farming that travels well and

actually works tolerably well for what I think of as "proletarian" production crops such as wheat, corn, cotton, and soybeans that tolerate rough handling. The effort of this agriculture to rise above, as it were, local soils, local landscape, local labor, local implements, and local weather makes it the very antithesis of vernacular agriculture. The Western vegetable garden has some, not all, of the same features. Though it contains many cultivars they are typically planted in straight rows, one cultivar to a row, and look rather like a military regiment drawn up for inspection at a parade. The geometric order is often a matter of pride. Again, there is a striking emphasis on visual regularity from above and outside.

Contrast this with, say, the indigenous field crops of tropical West Africa as encountered by British agricultural extension agents in the nineteenth century. They were shocked. Visually, the fields seemed a mess: there were two, three, and sometimes four crops crowded into the field at a time, other crops were planted in relays, small bunds-embankments-of sticks were scattered here and there, small hillocks appeared to be scattered at random. Since to a Western eye the fields were obviously a mess; the assumption was that the cultivators were themselves negligent and careless. The extension agents set about teaching them proper, "modern" agricultural techniques. It was only after roughly thirty years of frustration and failure that a Westerner thought to actually examine, scientifically, the relative merits of the two forms of cultivation under West African conditions. It turned out that the "mess" in the West African field was an agricultural system finely tuned to local conditions. The polycropping and relay cropping ensured there was ground cover to prevent erosion and capture rainfall year-round; one crop provided nutrients to another or shaded it; the bunds prevented gully erosion; cultivars were scattered to minimize pest damage and disease.

Not only were the methods sustainable, the yields compared favorably with the yields of crops grown by the Western techniques preferred by the extension agents. What the extension agents had done was erroneously to associate visual order with working order and visual disorder with inefficiency. The Westerners were in the grip of a quasi-religious faith in crop geometry, while the West Africans had worked out a highly successful system of cultivation without regard to geometry.

Edgar Anderson, a botanist interested in the history of maize in Central America, stumbled across a peasant garden in Guatemala that demonstrated how apparent visual disorder could be the key to a finely tuned working order. Walking by it on his way to the fields of maize each day, he at first took it to be an overgrown, vegetable dump heap. Only when he saw someone working in it did he realize that it was not just a garden but a brilliantly conceived garden despite, *or rather because of*, its visual disorder from a Western gardening perspective. I cannot do

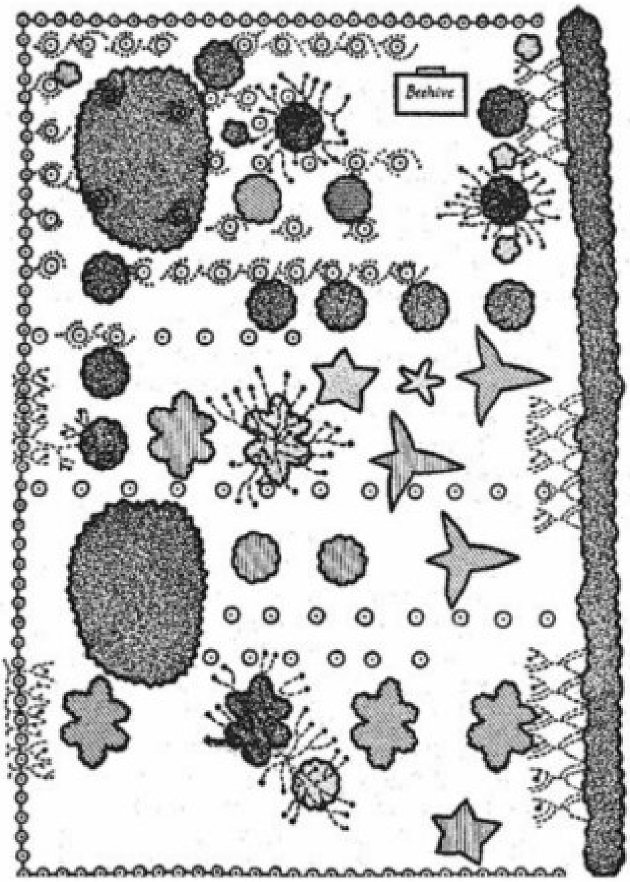

Figure 2.2. Edgar Anderson's drawings for the Vernacular Garden, Guatemala. (a) *Above* An orchard garden. (b) *Right* Detailed glyphs identifying the plants and their categories in the garden. Reprinted from *Plants, Man, and Life*, by Edgar Anderson, published by the University of California Press; reprinted with permission of the University of California Press

better than to quote him at length about the logic behind the garden and reproduce his diagrams of its layout (fig. 2.2). Though at first sight there seems little order; as soon as we started mapping the garden, we realized that it was planted in fairly definite cross-wise rows. There were fruit trees, native and European in great variety: annonas, cheromoyas, avocados, peaches, quinces, plums, a fig, and a few coffee bushes. There were giant cacti grown for their fruit. There was a large plant of rosemary, a plant of rue, some poinsettias, and a semi-climbing tea rose. There was a whole row of the native domesticated hawthorn, whose fruit like yellow, doll-sized apples make a delicious conserve. There were two varieties of corn, one well past bearing and now serving as a trellis for climbing string beans which were just coming into season, the other, a much taller sort, which was tasseling out. There were specimens of a little banana with smooth wide leaves which are the local substitute for wrapping paper, and are also used instead of cornhusks in cooking the native variant of hot tamales. Over it all clambered the luxuriant vines of various cucurbits. Chayote, when finally mature has a nutritious root weighing several pounds. At one point there was a depression the size of a small bathtub where a chayote root had recently been excavated; this served as a dump heap and compost for waste from the house. At one end of the garden was a small beehive made from boxes and tin cans. In terms of our American and European equivalents, the garden was a vegetable garden, an orchard, a medicinal garden, a dump heap, a compost heap, and a beeyard. There was no problem of erosion though it was at the top of a steep slope; the soil surface was practically all covered and apparently would be during most of the year. Humidity would be kept during the dry season and plants of the same sort were so isolated from one another by intervening vegetation that pests and diseases could not readily spread from plant to plant. The fertility was being conserved; in addition to the waste from the house, mature plants were being buried in between the rows when their usefulness was over.

It is frequently said by Europeans and European Americans that time means nothing to an Indian. This garden seemed to me to be a good example of how the Indian, when we look more than superficially into his activities, is budgeting time more efficiently than we do. The garden was in continuous production but was taking only a little effort at any one time: a few weeds pulled when one came down to pick the squashes, corn and bean plants dug in between the rows when the last of the climbing beans was picked, and a new crop of something else planted above them a few weeks later.

FRAGMENT 10

The Anarchist's Sworn Enemy

Over the past two centuries, vernacular practices have been extinguished at such a rate that one can, with little exaggeration, think of the process as one of mass extinction akin to the accelerated disappearance of species. And the cause is also analogous: the loss of habitat. Many vernacular practices have made their final exit, and others are endangered.

The principal agent behind their extinction is none other than the anarchists' sworn enemy, the state, and in particular the modern nation-state. The rise of the modern and now hegemonic political module of the nation-state displaced and then crushed a host of vernacular political forms: stateless bands, tribes, free cities, loose confederations of towns, maroon communities, empires. In their place stands everywhere a single vernacular: the North Atlantic nation-state, codified in the eighteenth century and masquerading as a universal. It is, if we run back several hundred yards and open our eyes in wonder, nothing short of amazing that one can travel anywhere in the world and encounter virtually the same institutional order: a national flag, a national anthem, national theaters, national orchestras, heads of state, a parliament (real or fictitious), a central bank, a league table of similar ministries similarly organized, a security apparatus, and so on. Colonial empires and "modernist" emulation played a role in propagating the module, but its staying power depends on the fact that such institutions are the universal gears that integrate a political unit into the established international systems. Until 1989 there were two poles of emulation. In the socialist bloc one could go from Czechoslovakia to Mozambique, to Cuba, to Vietnam, to Laos, to Mongolia and find roughly the same central planning apparatus, collective farms, and five-year plans. Since then, with few exceptions, a single standard has prevailed.

Once in place, the modern (nation-) state set about homogenizing its population and the people's deviant, vernacular practices. Nearly everywhere, the state proceeded to fabricate a nation: France set about creating Frenchmen, Italy set about creating Italians.

This entailed a great project of homogenization. A huge variety of languages and dialects, often mutually unintelligible, were, largely through schooling, subordinated to a standardized national language-often the dialect of the dominant region. This led to the disappearance of languages; of local literatures, oral and written; of music; of legends and epics; of whole worlds of meaning. A huge variety of local laws and customary practices were replaced by a national system of law that was, in principle at least, everywhere the same. A huge variety of land use practices were replaced by a national system of land tiding, registration, and transfer, the better to facilitate taxation. A huge number of local pedagogies-apprenticeships, tutoring by traveling "masters," healing, religious instruction, informal classes-were typically replaced by a national school system in which a French minister of education could boast that, as it was 10:20 a.m., he knew exactly which passage of Cicero all students of a certain form throughout France would be studying. This utopian image of uniformity was seldom achieved, but what these projects did accomplish was the destruction of vernaculars.

Beyond the nation-state itself, the forces of standardization are today represented by international organizations. It is the principal aim of institutions such as the World Bank, the International Monetary Fund, the World Trade Organization, UNESCO, and even UNICEF and the World Court to propagate normative ("best practice") standards, once again deriving from the North Atlantic nations, throughout the globe. The financial muscle of these agencies is such that failure to conform to their recommendations carries substantial penalties in loans and aid forgone. The process of institutional alignment now goes by the charming euphemism of "harmonization." Global corporations are instrumental as well in this project of standardization. They too thrive in a familiar and homogenized cosmopolitan setting where the legal order, the commercial regulations, the currency system, and so on are uniform. They are also, through their sales of goods, services, and advertising, constantly working to fabricate consumers, whose needs and tastes are what they require.

The disappearance of some vernaculars need hardly be mourned. If the standardized model of the French citizen bequeathed to us by the Revolution replaced vernacular forms of patriarchal servitude in provincial France, then surely this was an emancipatory gain. If technical improvements like matches and washing machines replaced flint and tinder and washboards, it surely meant less drudgery. One would not want to spring to the defense of all vernaculars against all universals.

The powerful agencies of homogenization, however, are not so discriminating. They have tended to replace virtually all vernaculars with what they represent as universal, but let us recall again that in most cases it is a North Atlantic cross-dressed vernacular masquerading as a universal.

The result is a massive diminution in cultural, political, and economic diversity, a massive homogenization in languages, cultures, property systems, political forms, and above all modes of sensibility and the lifeworlds that sustain them. One can look anxiously ahead to a time, not so far away, when the North Atlantic businessman can step off a plane anywhere in the world and find an institutional order-laws, commercial codes, ministries, traffic systems, property forms, land tenure-thoroughly familiar. And why not? The forms are essentially his own. Only the cuisine, the music, the dances, and native costumes will remain exotic and folkloric . . . and thoroughly commercialized as a commodity as well (ibid., pp. 47–56).

References

Benson, E. S. (2020). *Surroundings: A History of Environments and Environmentalisms*. University of Chicago Press.

BIPM. (2019). *Le Système international d'unités / The International System of Units ('The SI Brochure')* (9th ed.). Bureau international des poids et mesures. https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9.pdf

Darwin, C. (2008). *On the Origin of Species*. OUP Oxford.

Daston, L. (2019). *Against Nature*. MIT Press.

Daston, L., & Park, K. (1998). *Wonders and the Order of Nature 1150–1750*. Zone Books.

Dear, P. (2008). *The Intelligibility of Nature: How Science Makes Sense of the World*. University of Chicago Press.

Dear, P. (2012). Science Is Dead; Long Live Science. *Osiris*, *27*(1), 37–55. https://doi.org/10.1086/667822

Descola, P. (2014). *Beyond Nature and Culture*. University of Chicago Press.

Devictor, V., & Bensaude-Vincent, B. (2016). From ecological records to big data: The invention of global biodiversity. *History and Philosophy of the Life Sciences*, *38*(4), 1–23.

Enserink, M. (2018). Research on research. *Science*, *361*(6408), 1178–1179. https://doi.org/10.1126/science.361.6408.1178

Feyerabend, P. (1993). *Against Method*. Verso.

Forman, P. (2012). On the Historical Forms of Knowledge Production and Curation: Modernity Entailed Disciplinarity, Postmodernity Entails Antidisciplinarity. *Osiris*, *27*(1), 56–97. https://doi.org/10.1086/667823

Foucault, M. (1979). *Discipline and Punish: The Birth of the Prison*. Vintage Books.

Foucault, M. (2002). *The Order of Things: An Archaeology of the Human Sciences*. Psychology Press.

Gates, B. (2021). *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need*. Penguin UK.

Golinski, J. (2012). Is It Time to Forget Science? Reflections on Singular Science and Its History. *Osiris*, *27*(1), 19–36. https://doi.org/10.1086/667821

Gordon, D. (1984). The Image of Science, Technological Consciousness, and the Hidden Curriculum. *Curriculum Inquiry*, *14*(4), 367–400. https://doi.org/10.2307/3202263

Harmony of The Worlds (Episode 3). (1980). [Broadcast]. In *Cosmos: A Personal Voyage*. PBS.

Heisenberg, W. (1958). *The Physicist's Conception of Nature*. Harcourt, Brace.

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). Beyond WEIRD: Towards a broad-based behavioral science. *Behavioral and Brain Sciences*, *33*(2–3), 61–135. https://doi.org/10.1017/S0140525X10000725

Horkheimer, M., & Adorno, T. W. (2002). *Dialectic of Enlightenment*. Stanford University Press.

Kuhn, T. S. (1996). *The Structure of Scientific Revolutions*. University of Chicago Press.

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers Through Society*. Harvard University Press.

Lewis, P. J. (2017). Quantum mechanics, emergence, and fundamentality. *Philosophica*, *92*(2). https://doi.org/10.21825/philosophica.82111

Merchant, C. (1990). *The Death of Nature: Women, Ecology, and the Scientific Revolution*. HarperCollins.

Poincaré, H. (1905). *Science and Hypothesis* (J. Larmor, Trans.). The Walter Scott Publishing Co., Ltd.

Sapolsky, R., & Balt, S. (1996). Reductionism and Variability in Data: A Meta-Analysis. *Perspectives in Biology and Medicine*, *39*(2), 193–203. https://doi.org/10.1353/pbm.1996.0057

Scott, J. C. (2012). *Two Cheers for Anarchism: Six Easy Pieces on Autonomy, Dignity, and Meaningful Work and Play*. Princeton UP.

Shapin, S. (1996). *The Scientific Revolution*. University of Chicago Press.

Shapin, S., & Schaffer, S. (2011). *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*. Princeton University Press.

Stanford (Director). (2011, February 1). *21. Chaos and Reductionism* [Video recording]. https://www.youtube.com/watch?v=_njf8jwEGRo

UN Climate Change (Director). (2019, December 9). *Patricia Espinosa: "Science must be our common language" #COP25* [Video recording]. https://www.youtube.com/watch?v=5usZEwIdJyw