4 Substrate

θαλασσα διαχεεται και μετρεεται ειζ τον αυτον λογον οκοιοζ προσθεν ην ν γενεσθαι γη.
The earth melts into the sea as the sea sinks into the earth.
—Heraclitus, fragment 23

In chapter 2, we reprised salient concerns about the limits and powers of representation. I advocated shifting our technological perspective from the technologies and sciences of representation to those of performance, by which I intend improvising and designing continuously in continua of symbolic, embodying matter. To elaborate what that means will require the content of chapter 6 to flesh out what we mean by the continuous. For now, let us use continuity and continua in their intuitive senses, seeing how we might make sense of matter as living continua versus matter chunked as living and inert objects. I use "living" as a compact term linking Maturana and Varela's autopoiesis with Whitehead's processual notion of concrescence. More fully justifying the link will have to wait till chapter 5, but for now I will emphasize that we should always think of our continua as being in continuous variation.

My aim is not to "explain" what the world is made of, or how the world works, or how humans work. For that we should go to metaphysics, physics, cosmology, psychology, economics. Nor is my aim to explain to you what you must do to be good in the eyes of the gods. For that we could go to a church. Consider an analogous distinction between Taoism and a church-based religion as social and epistemic forms. Zhuangzi's parables ripple the smooth surface of thought, and discontent rational judgments but do not supplant them with an alternative rational judgment. The verses of the *Dao De Jing* do not work as dogma or scripture or moral stricture; their power is that of poetry. And although people appear as pedagogical devices in these stories, *Homo sapiens* is not the poetic subject. So although I have drawn much from phenomenological thinking, it should be clear that I do not pursue the Cartesian thread that is shared by Husserl, Heidegger, and Merleau-Ponty, ending in the present day with the cognitivists who have solved philosophy. My ambition here is not to settle old scores in metaphysics but to suggest an *expressive* mode of articulation that will

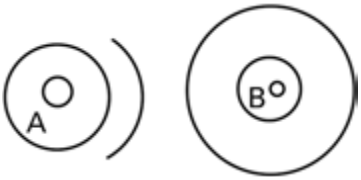


Figure 4.1
Field of superposable vortices, after David Bohm. Diagram by author.

accommodate poiesis and enchantment, by which I mean the transmutation (not transubstantiation) of material. Let me underline that I am *not* offering a new truth overturning yesterday's truth. Instead, I am poetically articulating the world as dynamical plenum, a conception that is as ancient as any other.

By the way, I do not object to objects or deny that they exist. Briefly put, my purpose is not to classify objects or their dual subjects, but rather to offer an approach to articulating objects as they come into being, as they emerge from continuous and continuously varying fields of media-material and then dissolve again into those fields.[1] Such an approach needs to move carefully to avoid appealing to a priori objects, a challenge even more difficult than inventing a model-free "learning" algorithm, which is an epistemological project rather than an ethico-aesthetic and material project.[2] This articulation should accommodate suppleness, nuance, *fresh*[3] expression.

In this chapter, and throughout this book I will use *media* and *material* interchangeably to lexically remind us of the materialist and topological thrust of this project: that media is material as much as material is media. To reiterate: material for me is an amalgam of matter + energy + affect. (This is a creative axiom like what Stengers meant by "propositional.") The middle term, *energy*, is more than the energy of modern (nineteenth-century) physics, since it can be constituted of money in flux or force × time or other types of energy, depending on how we are attuned. Media for my purposes is the mode in which language resonates materially and corporeally, but this asignifying mode, to use Guattari's term, works below the level of meaning. If we take an interest in materiality via media, then it makes sense to look for a variety of ways in which media acts materially. *This motivates creating computational media, because the computational affords boundless and intricate ways to construct media with experimentally different sorts of behavior than what one expects from noncomputational media like water, wood, tissue, and sinew*.

For my purposes, an essential aspect of materiality is its temporality. Consequently, understanding what we can do with time-based computational media should afford more ample insight about dynamical matter, or material dynamics, in general. One strategy I take is to transmute questions about things, or more precisely monads, into questions about stuff, or *plenum*.[4] In particular, instead of puzzling about the tempo-

rality of objects, I would ask what makes material material. Adapting Whitehead's observation "actual entities perish"[5] to a plenist ontology, then, we should say "materials" perish, which should seem no more and no less mysterious than saying that yogurt has a shelf life.

In the next section, I present what is at stake, followed by a section summarizing some problems with atomistic, object-oriented ontologies. Subsequently, I describe a Heraclitean view of a continuum, a plenist world, and close with some implications. Throughout I use figurative language to lay out tropes, lures for feeling, motivating the much more precise modes of articulation that I will build in chapter 6.

Finally, if we want to answer the question *What is an object?*, we can readily set up speculative experiments using computational media or computationally thickened and nuanced physical events.

The Stakes

Before diving into the nature of this plenist orientation, let's take a moment to review what is at stake with this alternative. Akeel Bilgrami laid out the stakes in an eloquent passage that merits citing in full:

> In the dissenting tradition—which was a scientific tradition, for there was in fact no disagreement between it and Newton and Boyle on any serious detail of the scientific laws, and all the fundamental notions such as gravity, for instance, were perfectly in place, though given a somewhat different metaphysical interpretation—matter was not brute and inert but rather was shot through with an inner source of dynamism that was itself divine. God and nature were not separable as in the official metaphysical picture that was growing around the new science. . . .
>
> The link between Gandhi and the dissenters is vivid and explicit. One absolutely central claim of the freethinkers of this period in the seventeenth century was about the political and cultural significance of their disagreements with the fast developing metaphysical orthodoxy of the "Newtonians." Just as Gandhi did, they argued that it is only because one takes matter to be brute and stupid, to use Newton's own terms, that one would find it appropriate to conquer it with the most destructive of technologies with nothing but profit and material wealth as ends and thereby destroy it both as a natural and a humanitarian environment for one's habitation. In today's terms, one might think that this point was a seventeenth-century predecessor to our ecological concerns, but, though there certainly was an early instinct of that kind, it was embedded in a much more general point (as it was with Gandhi, too), a point really about how nature in an ancient and spiritually flourishing sense was being threatened. Today, the most thoroughly and self-consciously secular sensibilities may recoil from the term spiritually, though I must confess to finding myself feeling no such self-consciousness despite being a secularist, indeed, an atheist. The real point has nothing to do with these rhetorical niceties. If one had no use for the word, if one insisted on having the point made with words that we today can summon with confidence and accept without qualm, it would do no great violence to the core of one's thinking to say this: the dissenters thought of the world not as brute but as suffused with value. That they

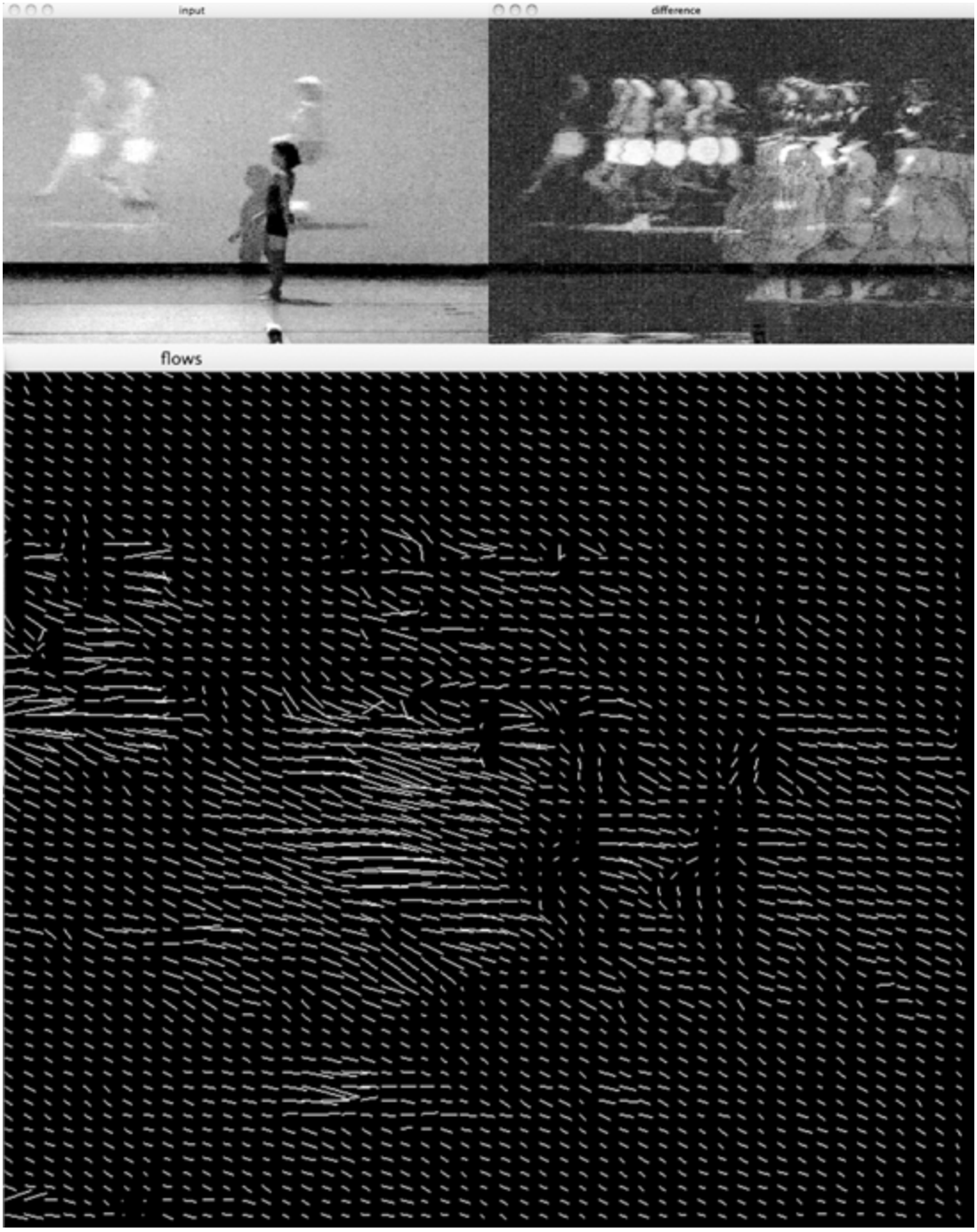


Figure 4.2
Real-time motion analysis with cv.jit Max/Jitter library: (A) live video of dancer, (B) optical flow as gradient (difference) density, (C) optical flow as vector field. Note that in (B) both the body's and projected image's movements produce optical flow.

happened to think the source of such value was divine ought not to be the deepest point of interest for us. The point rather is that if it were laden with value, it would make normative (ethical and social) demands on one, whether one was religious or not, normative demands therefore that did not come merely from our own instrumentalities and subjective utilities. And it is this sense of forming commitments by taking in, in our perceptions, an evaluatively enchanted world, which—being enchanted in this way—therefore moved us to normatively constrained engagement with it, that the dissenters contrasted with the outlook that was being offered by the ideologues of the new science. A brute and disenchanted world could not move us to any such engagement since any perception of it, given the sort of thing it was, would necessarily be a detached form of observation; and if one ever came out of this detachment, if there was ever any engagement with a world so distantly conceived, so external to our own sensibility, it could only take the form of mastery and control of something alien, with a view to satisfying the only source of value allowed by this outlook—our own utilities and gain.[6]

In the *Nature of Order*, architect and prophet Christopher Alexander called for exactly this sort of physics fusing matter and value à la Spinoza, rather than matter formed only by geometry (Einstein) or number (Pythagoras). My concern is indeed to explore the qualities of matter construed this way—as laden with value. I transmute Whitehead's axiom of process philosophy, *"How an entity becomes constitutes what the entity is*,"[7] to move from a concern about values of objects to concerns about value-generating or value-signifying processes. Classical metaphysics oscillates between pre-constituted subjects perceiving, reasoning about, and acting on preconstituted objects. Sidestepping both realist and idealist theories, in this chapter I consider objects, subjects, values, and relations all coconstituting each other in the dynamic of the stuffs of which they are made. One key feature of this account is plurality: there can be boundlessly many fields of potential. Another is dynamism—perceived as poiesis. We will see how value can arise out of the superposition of dynamic fields without requiring us to preconstitute particular subjects, or follow a totalizing telos. This relies on a triple conceptual transmutation: (1) shifting from objects to material fields ("stuff"), (2) shifting from objects to processes, (3) shifting from values as predicates to processes that produce value. The three aspects of this transmutation will take us through our discussions of the phenomenology of performance, substrate, and ontogenesis; this chapter concerns substrate. Before we launch into the chapter, let me state the key propositions succinctly. Until I tell a story in which these propositions take on life, we should not expect their significance or relationships to one another to be self-evident, but nonetheless I state them here as a map of what is to come. First, let me adopt a notation: conventionally in mathematics, the sign "⇒" means "implies." Let me read this sign to mean permits, allows, sustains, articulates.

(1) A *connected*[8] plenum is a condition of possibility for ethics.
(2) *Field* ⇒ *potential dynamics*. *Field* ⇒ *multiplicity*.
(3) *Affective intensity* constitutes value, and so is *primordial* (as substrate) to *ethical action*.

(4) *Care*, an affective field, nuanced by attunement and pathic sensitivity, is *primordial* to *politics*, an ever-dynamical system.
(5) *Continuity* (in the space of variations of plenum) ⇒ *nuance and poiesis: the textural natality of material*.

Atomism: The Problems of Complexity and Intersubjectivity

There are formal and ethical problems with atomism. The formal problem is that an atomic concept of the world sooner or later must come to terms with combinatorial complexity. The actual world, with its perverse habit of constantly producing more and more things over time, tends to outgrow every static categorization into a finite number of finite categories, every synchronic schema no matter how carefully reasoned. From modern science, the periodic table and the taxonomy of animals and plants epitomize this categorical approach. But why can the chemists and physicists keep their periodic table so tidy when the biologists have had to revise their classifications ever since Linnaeus? The classification of life forms has proliferated whole kingdoms, even to the point of blurring boundaries between them and between life and nonlife, a liminal region occupied by prions and organic molecules weighing six-figure daltons. Of course, physicists have the luxury of scoping their discipline to exclude much of the richness of the material world, leaving for example the messy work of rationalizing alchemy to the modern day chemist and astrologer. In fact, under the impact of successive waves of industrially powered material experimentation and innovation, we see a proliferation of categories of matter in modern chemistry: plastics, pharmaceuticals, and now some nanomaterials being absorbed into this second oldest of technologies (the oldest being cooking). All these taxonomies, especially those that maintain an ambition to categorize the entire unfolding world, share a common strategy, which is to partition their categories into hierarchies. A hierarchy contains towers of categories, where an element of a given category contains elements from a subcategory. But this does no more than sweep the problems under the rug, because in a given category we still face the same formal structure.

A word about discrete sets in computer science. Faith in the generality of discrete atomism has been canonized in software programming languages from LISP to Java in which a "set" is always defined as an unordered, finite list of discrete elements. (ML, a rare exception, represents categories as first-order entities in the language, and so can define a set without any concrete representative of that type.) A "set" characterized as an unordered list may seem like the height of unconditioned generality to a programmer, but it can in no way encode even the unit interval [0,1] of all real numbers between 0 and 1 (inclusive), much less the transfinitely larger set of all measurable functions mapping the interval I to itself. (Chapter 6 will develop the concepts needed to understand this more clearly.) "Arbitrary and finite" means that although the formal structure does not impose any limit on the number of items, any

instance of a "set" has only a finite number of items. "Arbitrary" just means that the cardinality of the set is not a preordained constant in the formal scheme. An arbitrary set can be finite or infinite. In a programming language, it is always finite, of course, and in practice limited by machine memory. What breaks this formal finiteness in a programming environment is the data "stream." A stream of data is a pipe to the world outside the program through which an arbitrary and boundless number of packets of data can enter over time. A video channel that takes data of unspecified size from a server can be represented as a stream in the program. Another example is a stream kept open to pass data from a sensor. In both cases, the program opens itself to the temporal: it enters the temporal world and waits for objects (packets) to be sent from the world. So it is the temporality of the world, its ever-changing state, that breaks the assumption of a formal, bounded, discrete, and hence finite data storage structure. (We will return to this in chapter 5.) Now, as everyone has been told for the better part of a century, the computer's canonical atom has been the bit, which can take on only one of two values: 0 or 1. We can regard this as a special case of the generally atomistic view of the world.

So, with this canonical example from the digital epoch in hand, let's turn to the formal problem of atomism. Our world contains not only things but also relations of things, so this induces a combinatorial complexity. Such complexity has often been valorized as yielding phenomena emerging from large collections of discrete entities in networks of relations modeled on graphs, phenomena that one does not observe in an individual entity. However, as I have said before, combinatorial complexity does not equal richness. Indeed complexity inevitably tends to overwhelm sense and value.

For the sake of completeness and clarity, let's consider the following exercise. Suppose a discrete set S contains exactly N elements. One says that the size of S is N. The set of all subsets of S, called the powerset of S, generally has larger size than S. In fact, if S has cardinality N, then its powerset has size 2^N, a much larger number than N. If a set has ten elements, then its powerset has about a thousand subsets. If S has twenty elements, then its powerset has more than a million subsets. In other words the powerset of a set S is exponentially bigger in cardinality than S itself. Generally, discrete structures exhibit this sort of combinatorial, exponentially explosive complexity as you add more elements, components, or dimensions to the structure. The same is true of networks of discrete nodes and arcs. As these networks grow larger, we can attempt to salvage the situation by aggregating subgraphs into nodes, but that merely defers the explosion by one step. Eventually combinatorial complexity overwhelms us. On the other hand, if we believe that human experience is continuous, dense and rich but not combinatorially complex, then it should be a healthy challenge to try to make our performance technologies themselves topological rather than combinatorial.

So to account for relations among a universe of objects requires combinatorially and exponentially complex structures. And one lesson we can easily verify from

collective as well as individual life is that exponential growth outpaces any finite bound, in a shockingly rapid way.

Exercise: To get a feel for exponential growth, take a sheet of paper, of any size. Fold it in half. Take this halved piece of paper and fold it in half again. Repeat. How many times can you do this? How does this depend on the width of the sheet? Try a larger sheet of paper, of any size. This is an exercise that you must do with your own hands on a physical sheet of paper in order to appreciate. It is not a *Gedanken* exercise but a material, corporeal one. Each time you fold, you are doubling the thickness of the folded paper, which is an exponential increase in thickness: $2^N \times$ original thickness of the paper.

So much for technical, practical problems with discrete sets and the combinatorial complexity of atomistic representations. But more fundamental, conceptual problems with an atomistic, object-oriented ontology abound. For instance, it makes it hard to account for change. Indeed, Whitehead's entities are "changeless," so he needs to jump through some hoops in order to accommodate the dynamic.

In fact, both difficulties are artifacts of the atomistic object-oriented ontology. They go away under others.

There is a tendency to transcendentalize—to treat material as if it were abstract and to dematerialize any concept from its material field. This includes a transcendentalization of objects, classes of objects, and reasoning based on objects.

Another problem is the reification error: just because you provide a name or label does not necessarily imply that the named or labeled thing exists. ("Let X = Four-sided triangle.")

Still another problem is the commodification of artistic process and its products. On a macroscopic scale, this is related to the formation of corporations as legal persons. And that in turn is part of a general well-rehearsed critique of the metaphysics of presence and totalizing narratives. In light of all these difficulties, it is hard for an atomistic theory to account for intersubjectivity or intersubjective experience.

Another and to my mind the most critical problem with atomism, as intractable—perhaps more so—as its formal complexity, is its ethico-aesthetic inadequacy: how could a set of isolated, atomic egos ever come to share a common experience of the world? This basic problem of intersubjectivity, has plagued philosophy throughout its history, but assumes a peculiar intensity as a problem for Husserl and Heidegger. Moreover, how would these atomic subjects come to *care* about one another if it is not clear how one consciousness can even know what another consciousness knows? The first problem is perceptual and epistemological. But the second is ethical, political, and phenomenological. *Pace* zombie theorists, who deny interior experience, and solipsists, my question is not *whether* we can act as if we know and feel another, but *how*. It is a *pragmatic* ethico-aesthetic question whose implications depend on one's attitude toward representational schemas.

Let me add a comment about hierarchies. It may seem odd that cyberlibertarian engineers and allied theorists who inveigh against political hierarchy extol the formal virtues of hierarchical (modularity and nested grouping) representation as a solution to the world's profligate and exponential behavior. But this becomes more comprehensible when we understand that their allegiance is oriented not so much to hierarchies but to objects in themselves, singular and autonomous. One could read this as a wishful projection of *Homo sapiens*'s willful freedom into the ontology of the world.

To be fair, discrete sets can admit far more complex structures than what I have enumerated here. We have barely reached the shores of algebra, and will not be able to do much more in chapter 6 than name the simplest of these: groups, rings, fields, and structures upon structures such as exact sequences and homological algebras. But the technical and, most critically, the ethico-aesthetic problems remain in force for any commitment to an atomistic ontology.

But enough negative critique, at least for the moment! What if we view the world not as a vacuum raisined with corpuscles but as a *plenum* instead? What if we construe and construct our world as a single medium varying through boundlessly many modes of articulation, continually exfoliating in a value-creating magma of experience? What this conception affords us will be the subject of the rest of this book.

It's an old alternative, of course, one that courses in the West from Heraclitus through Spinoza, Leibniz, Serres, and Deleuze, and in the East from Laozi to the present. Referencing Laozi prompts an amateur comment about Chinese brush painting. One of the striking characteristics of Chinese painting is that the repertoire of brush techniques continuously span what in the West are distinct forms of graphical expression: characters of poetry in calligraphy, the human figure, landscape, and details of plants or animals. All these very different entities emerge from differential intensities and local contexts from a common substrate impregnated with water inks. We will return to this later.

Substrate, Fire, Water, Field

> Forms interact not with forms but with their background, . . . the reservoir of the tendencies of all forms even before they had separate existence or constituted an explicit system.[9]
>
> —Gilbert Simondon

Substrate

What is a watermark? Of what is a watermark made? We see the watermark as immanent in the substance of the paper—it is not made of some physical material other than the paper, such as a glyph written in ink, and yet it has form. Moreover, its form does not obscure, and cannot be eliminated by what is inked over it. Physically

reshaping the paper necessarily reshapes the embedded watermark. So the paper is the substrate in which the watermark takes form.

So *substrate* means the stuff of the world, the material coextensive with all the actual entities made of it. If this hyletic substrate is always and everywhere in dynamical transmutation, to what poetic figures can we appeal in order to articulate matter + energy + affect?[10]

Running Water

Some leaves fall into a river and swirl away in the flow of the water. Some leaves twirl into an inlet by the shore and spiral round and round with the coiled water, while others float downstream. The leaves jostle one another flowing along their own trajectories. By the shore, someone downstream can see those leaves coming from unseen origins and going around the bend to unseen fates. The leaves are not the water in flux but they make visible the movement of the water's current, at least at the surface. We use this humble example to guide our foray into a qualitative and later topological approach to dynamical systems.[11]

Similarly, a wave in the ocean is not some dust or leaves laid on top of the water nor even the water as substance, but a shape that moves through the water. Moreover this shape is constantly in motion with respect to the constituent fluid: a particular molecule of water will be in a given wave, and then pass out of the wave. Even in the striking example of a water wave standing still with respect to the banks of a river, the water itself is flowing downstream so the constituent water actually is progressively displaced with respect to the standing wave. Therefore by symmetry the wave is in motion with respect to the water. It is in just this sense that a wave takes form in its substrate.[12]

Water Music

Exercise: Dip a finger into a basin of water and make ripples continuously. See how the ripples lap against the edges of the basin. Dip a second finger somewhere else in the water and make a second set of ripples continuously. See how the first ripples continue to lap against the walls of the basin as before, even though they superpose with the second set of ripples as they pass through one another across the water's surface.

Imagine replacing the water by a sheet of wood. Drumming your fingers on the wood makes ripples as well, but the wood vibrates at such high frequencies—frequencies that are a function of the stiffness and density of the material medium—that you cannot see them. But you hear the vibrations as timbre, and, in the refined shapes of musical instruments played tonally, you hear them as pitch.

Music Sound

Music provides, as always, one of the richest substrates articulating matter + energy + affect, but since Schönberg we have come a long way from conventional discrete pitch

scales, harmonic structures, and time signatures. As Deleuze and Guattari wrote in their chapter on linguistics:

> But when chromaticism is unleashed, becomes a generalized chromaticism, turns back against temperament, affecting not only pitches but all sound components—durations, intensities, timbre, attacks—it becomes impossible to speak of a sound form organizing matter; it is no longer even possible to speak of a continuous development of form. Rather, it is a question of a highly complex and elaborate material making audible nonsonorous forces. The couple matter-form is replaced by the coupling material-forces.[13]

Deleuze and Guattari's embedding of music into its continuous substrate also holds for speech:

> There are many procedures for placing the voice in variation, not only Sprechgesang (speech-song), which constantly leaves pitch behind by descent or ascent, but also circular breathing techniques and zones of resonance in which several voices seem to issue from the same mouth. . . .
>
> [E]thnomusicologists have found . . . cases . . . where a first, diatonic, vocal part is superseded by a chromatic descent into a secret language that slips from one sound to the next in a continuous fashion, modulating a sound continuum into smaller and smaller intervals until it becomes a "parlando" all of the intervals of which blur together—and then the diatonic part is itself transposed according to the chromatic levels of a terraced architecture, the song sometimes interrupted by a parlando, by a simple conversation lacking definite pitch.[14]

Following Deleuze and Guattari's lead, let us return from sound to speech, holding on to acoustic density and contingencies of sound in matter and flesh.

The Hubbub installation based on speech recognition has multiple parentage. Aside from the obvious concerns with public speech and lettering in public space,[15] the installation populates the theoretical gap between speech and text by materializing glyphs that dance according to the prosody of live speech but persist with text's iterable durability.

But deeper concerns inform Hubbub. United States law recognizes "fighting words"—utterances that when spoken under certain conditions have the same legal impact as a physical blow, so that you can sue for such speech as if you had been physically attacked.[16] Why? Beyond the semantic content of the words, speech is sonic; its sonic field copermeates both the body of the one who speaks and the one who hears, rendering them acoustically coincident in their tissue and blood. Ethically one holds responsibility for what one does corporeally with respect to another body. Therefore the sonic field, since it permeates all bodies present, constitutes an ethical medium by its very transcorporeal extension.

When a doctor lays her hand on you, her patient, she performs the most ancient medical technique: *palpation*. Palpation—the laying of hands on a body—does two things. It is an act of finding, of determining the situation of the patient, and as such it can be regarded as an analytic act. But it is also an ethical act: by laying a hand on

the body of the patient, the doctor effectively and affectively affirms: "I am taking you into my care, I am now responsible for your well-being." She is literally and corporeally reenacting her oath.

What is essential in this example as in the previous is the superposition of two fields of living material, breathing and pulsing together for a duration. To carry out palpation, it would be a contradiction to separate the physician and her patient into two disjoint bubbles of the world. This epitomizes an essential quality of any ethical medium, that is, its inseparability, or, to anticipate a more precise concept: its *(topological) connectedness*. And so we arrive at the first proposition:

(1) A connected plenum is a condition of possibility for ethics.

Anticipating the discussion of topology in chapter 6, separation or connectedness do *not* necessarily refer to what can be marked off by ordinary Euclidean geometry. Topology articulates proximity without relying on metric distance or geometry. By a topology induced by the flow of matter in the universe over the scale of eons, some of the atoms in the hair of the doctor and the patient and some atoms in the fabric of the chair may be regarded as being in the same "open set," because in the distant future they will be whirling in common orbits about the same compact neutron star that our sun will one day become. However, other atoms of the doctor and her patient may wind up floating into relatively uncorrelated paths (during the epoch in which a classical physics perspective is adequate), and therefore regarded as not so proximate to one another. It's for such situations that the topological concepts of an open set and connectedness seem well adapted.

Or the topology could be a very different one, induced by the set of touchings, of all the ways that a touching—which is simultaneous with being touched—can be felt to resemble or recall other touchings in any event that the doctor and her patient have experienced. You can imagine that there is no reason at all for such a set to have anything like the structure of a Euclidean space $\mathbb{R}^n$. And the notion of proximity in the set of touchings (which is not a geometrical space) may have to do for example with all the emotional intensities that a touching evokes as well as the social codes deriving from such intensities. People speak of feeling disconnected, or that someone seems disconnected. This disconnection may not have to do with physical contiguity but, as in this case, with a separation between the touchings that the doctor feels appropriate to carrying out her medical responsibilities and the touchings that the patient feels appropriate to being the subject of medical attention. Although irreducible to data and utterly contingent, the separation can be quite marked and even stable in the sense that no sufficiently small perturbation of a careful touching turns it into a careless touching.[17] This gives an example of where a concept of topological separability can serve in very rich situations that cannot and should not be reduced to geometric schema like boxes or grids or any rule-governed stratification.

This example of touching brings out an essential aspect to which I would like to direct attention, away from classification of actions and to the dynamical substrate within which any action takes place and shape. Noticing that Deleuze and Guattari's turn of phrase "coupling material-forces" makes explicit the dynamical aspect of material, let's proceed from the notion of substrate to the heart of a *field-oriented* approach to substrate: its dynamism.

Heraclitus's Fire

At some point in a child's life, he or she wonders at fire. This wonder may or may not be articulated in words, but nonetheless the child marvels and wonders: What is fire? Is it fuel or is it light? Is it matter or is it image? How is it that it consumes its fuel but does not consume itself? In an alchemical, poetic, and cultural meditation in a design course about materials, Yoichiro Serita once observed that fire has this peculiar material behavior: as a substance, it tends to expand without limit; it does not observe the conservation law obeyed by ordinary matter. So thinking of fire amplifies our notion of matter.

Process philosophy in the West found one of its greatest early poetico-cosmological exponents in Heraclitus. Immediately before him came the first natural philosophers, the Milesian *physikoi* of the sixth century BCE: Anaximander, Anaximenes, Xenophanes, who created ways of looking at the world in terms of its physical contents and dynamics rather than in lyric accounts of the actions of heroes and gods.

By no means, however, did the natural philosophers exclude the superhuman from their cosmologies. Xenophanes proposed, primordial to Homer's all-too-human pantheon, a cosmic god "similar to mortals neither in body nor in thought,"[18] opening the way for a power that was not anthropomorphic but a principle of the dynamical universe. Pythagoras constructed geometric order from which one could derive both eternal and material, mortal patterns. In addition to, informed by but not limited to, the mundane physics and geometry of the *physikoi*, Heraclitus created a poetic, multivalent complex of a dynamical plenum. The literary context of Heraclitus's time and the syntax of his language suggest that his figures, such as the most famous ones about fire and the river, speak to far more than what we typically consider the purview of modern physics, binding cosmic pattern with the material and with mortal and nonmortal experience.

Milesian and Ionian cosmology interpreted "physical change as a conflict of elemental powers within a periodic order of reciprocity and symmetry recognized as just"—*dike*.[19] But departing from the natural philosophers, Heraclitus's poetic construction took on quite a different order, in which the cycling of matter was fused with a human and even cosmic order of justice in reciprocity. This interpretation placed the mortal notions of justice in a much vaster yet immanent frame of the principle of turning-into-the-opposite.

Table 4.1

κοσμον τον αυτον απαντον αυτε τιζ θεων ουτε ανθρωπων εποιησεν, αλλην αει και εντιν και εσται πυρ αειζωον, απτομενον μετπα και αποσβεννυμενον μετρα.	*The ordering, the same for all, no god or man has made, but it ever was and is and will be: fire everliving, kindled in measures and in measures going out.* (Heraclitus, fragment 37, Kahn pp. 44–45.)
πυροζ τροπαι πρωτον θαλασσα, θαλασσηζ δε το μεν ημισυ γη, το δε ημισυ πρητηρ.	*The reversals of fire: first sea; but of sea half is earth, half lightning storm.* (Heraclitus, fragment 38, Kahn pp. 46–47.)
Θαλασσα διαχεεται και μετρεεται ειζ τον αυτον λογον οκοιοζ προσθεν ην η γενεθαι γη.	*Sea pours out <from earth>, and it measures up to the same amount it was before becoming earth.* (Heraclitus, fragment 39, Kahn pp. 46–47.)
πυροζ ανταμοιβη τα παντα και πυρ απαντων οκωσπερ ξρυσον κρηματα και κρηματων κρυσοζ.	*All things are requital for fire, and fire for all things, as goods for gold and gold for goods.* (Heraclitus, fragment 40, Kahn pp. 46–47.)

From *The Art and Thought of Heraclitus: An Edition of the Fragments with Translation and Commentary*, ed. and trans. Charles H. Kahn (Cambridge: Cambridge University Press, 1979).

It is against this cosmological frame that we can interpret four fragments of Heraclitus concerning fire.

It is crucial to understand that Heraclitus's fire is not just one of the four terrestrial elements codified by Aristotle three centuries later, but the universal agent of change of state, and the mediator of exchange analogous to gold's function for goods. Heraclitus's fire acts simultaneously upon the cosmos, the hearth, and the furnace, in other words universe, home, and technology. Fragments 37 and 40 state that the Heraclitean "fire" is the everlasting principle vitalizing the entire universe, κοσμον (*cosmon*, ordering); in other words, his is a *monist* ontology, but a thoroughly dynamic and intimate one. As Kahn writes,

> Fire is indeed a mysterious symbol of life, of superhuman life—despite or because of the fact that it is the one element in which no animal can live, and a power that . . . often served to receive human bodies at death. Thus representing life and creativity it also represents death and destruction. . . .
>
> *[Fire] is not itself a kind of matter, not a body at all, but a process of transition from one state to another* . . . [emphasis added].[20]

So what are the dynamics of Heraclitean fire? We get a hint when we note that a key term in 38 is τροπαι (*tropai*)—reversal, connoting the rout of an army as well as the inflection of path of the sun at the two solstices of the year. And in fragment 49, Heraclitus simultaneously describes physical dynamics and lived experience in terms of a condition becoming its opposite:

> XLIX (D. 1 26) Cold warms up, warm cools off, moist parches, dry dampens.[21]

This transformative principle of C into not C, combined with the reflexive principle (not not C) = C, yields an eternal cycle which anticipates the fundamental role of the harmonic oscillator as a model of physics from Newton to the present day.

Moreover, we can regard Heraclitus's "measures up to the same amount" (μετρεεται) in fragment 39, and the balanced measure (μετρα) of fire kindling and extinguishing in 37, as stating a principle of conservation of matter-energy. Obviously, this statement referencing measure concerns not numerical metric but proportionality and, in fact, symmetry or reciprocity. In modern times, this reminds us of one of the more profound foundational theorems of the calculus of variations, by Emmy Noether. Colloquially phrased: to every symmetry of a variational system corresponds a conserved quantity. We do not have modes of articulation adequate to describe Noether's theorem more precisely and meaningfully, but let me immediately note that in the twentieth century we came to question the ubiquity of this theorem.[22] What that means is that in some situations either matter + energy + affect is not conserved or there is no invariance of the dynamical system under any ("infinitesimal variation of the parameters") local variation field. Now, what this has to say about care potentially as a substrate for ethics and politics remains to be worked out in this chapter and in work beyond the scope of this book. But to start the work, consider the Golden Rule, *do unto others as you would have them do unto you*. It assumes, to adapt a notion more rigorously defined later in this chapter, *isomorphic* subjects. In other words, you and your others are the "same" as ethical subjects. You and others have the same interests and desires. It also assumes that the only relevant forces are humans, anthropic subjects. But if we are to try to avoid making Man the center of the eco-ethical universe, to come up with some modes of articulation that are not so tautologically or solipsistically anthropocentric, it should be relevant to understand how to relax the anthropocentric notion of symmetry underneath the Golden Rule to a nonanthropocentric understanding of the relation between symmetry and the dynamics of matter, energy, and affect that we have begun with Heraclitus. In our context, these modes of articulation generalize ethico-aesthetic dynamics that in human terms could be understood as the dynamics of *caritas* or care to a cosmological setting.

These three principles of *reversal*, of *conservation* under transmutation, and of *symmetry* do not completely articulate ontogenesis, but at least they can serve as ingredients of a dynamical ontology. And we can discern some patterns in this ceaseless flow of change that Heraclitus describes in his most celebrated statements, fragments 50 and 51:

L (D. 12) As they step into the same rivers, other and still other waters flow upon them.
LI (D. 91) Plutarch: [According to Heraclitus one cannot step twice into the same river, nor can one grasp any mortal substance in a stable condition, but by the intensity and the rapidity

of change it scatters and again gathers. Or rather, not again nor later but at the same time it forms and dissolves, and approaches and departs.][23]

In Kahn's view, Heraclitus's statements about the dynamics of the world do not claim that identities are unstable—indeed "the river" is a stable object—but rather that the state of the river, and one's experience of the river, are never static, and therefore not necessarily identically constant. This observation bears remembering. It will serve us well as the core of the performative. It anticipates quantum mechanics' inextricable intertwining of the observer and the observed (precisely scaled by Planck's constant), which may offer deep insights for the theatrical duality between spectator and actor. Given this Heraclitean principle, which works as the *potential* of change, let's turn to consider the qualitative dynamics of matter.

It may be richer and more fruitful to imagine material dynamics born of Heraclitean fire rather than Aristotelian substances, each with their own fixed formal and material dynamics. Building on Heraclitus's conception, we can posit manifold bundles of potential fields, as many as there are spectra of flames. We can posit fields of potential force extending throughout the material manifold, i.e., the world. Since there can be multiple passions in play at the same time, we posit multiple fields for their superposability (to be made precise in chapter 6). These fields may act at multiple scales, may be restricted to or concentrated in various parts of the material manifold, or may even be functions not of the base manifold but of its spatial derivatives, in other words of the *variation* of densities of the material manifold, rather than the densities (objects) themselves.

We can think of a field, roughly, as a continuous distribution of potential with respect to the actual world. Even for a fixed actuality, were that possible, there are uncountably many fields of potential. And the structure of the potential can vary uncountably as well. We can be more precise in chapter 6, but for now imagine for example the fields of repulsions and attractions that condition how lava, capital, or individuals flow within their planes of immanence.

I propose to adopt a field-theoretic attitude (and after chapter 5, a topological articulation of a field-theoretic attitude) and see what becomes of the world and of our inhabitation in the world under such a perspective. What happens to language and languaging, to computational media and computational process, to subjects and objects under a field-theoretic approach? To summarize this compactly as our second proposition:

(2) Field $\Rightarrow$ potential dynamics. Fields $\Rightarrow$ multiplicity.

Affective Intensity

If affective intensity is a scalar density, its gradient with respect to the material manifold—how it varies along with the extensive distribution of the material

manifold—is directed. This variation with respect to a given direction has an intensity, so it is vectorial, with direction and intensity. (To anticipate chapter 5, this is a precise formulation of Whitehead's vectoriality of prehension.)[24] In fact, any differentiable distribution—a scalar intensity—gives rise to a vectorial gradient. But there can be vectorial fields that are *not* gradients of a scalar intensity: namely those that have sources and sinks, singularities. In any case, an affective field yields a directedness with respect to which one can articulate dynamics and concentrations of relations and subjects, organisms, collectives, nexus. That these are *affective* fields implies by definition that they induce value, or to be more precise, they induce processes that articulate value. That these concentrations or densities, particularly compact ones (again anticipating chapter 6 where I will give a precise notion of compact), can be identified as subjects in affective relations with respect to one another makes them ethical subjects. In other words, *it is with respect to the vectorial fields of value that actions arise and can assume ethical force*.

We can gain some insight from this way of articulating ethical dynamics from affective intensity. To take one consequence: we do not have to preidentify or preposition ethical subjects, any more than we need to preidentify a charged particle to have an electromagnetic field. Indeed we can borrow the notion of a test particle. In order to understand how a potential, vectorial field can induce actual dynamics, one can experimentally place a "test charge" and see how it moves under the influence of that field. Or one can place an actual charged body and witness how it moves. But the field extends through the world, and there is no place where it does not "exist," though it may be attenuated or even zero in value. There is an essential difference between saying that the field does not exist at some place on the manifold and saying that it exists but is of value zero. To take the example of electromagnetism, a charge placed at a location where the electromagnetic field is zero does not move. But to say that the electromagnetic field is undefined at some point would mean that one cannot make any statement at all about what a charge placed at that location would do.

To more satisfactorily explore consequences of this would take another project, but let me make this initial observation. Recall that, as I said in the chapter 1, this project has been motivated by whether it makes sense to hyphenate ethico-aesthetics, and how it makes sense to improvise ethico-aesthetically. Recall also that we set aside appeals to transcendental, a priori, and teleological schemes on one hand and random schemes on the other, the former because they are rigid or brittle, the latter because they are boring by definition, and both because we are after the vast region of artful gesture in between. What I suggest is a more nuanced account of material articulation coshaping ethico-aesthetic potential that is neither overdetermined by originary or teleological schemes nor random.

Now it is fair to wonder how much richness of potential action this mode of articulation could sustain. Since there can be multiple affective intensities, indeed as many

as can be imagined, there can be a multiplicity of fields of value. In fact, in principle the space of possible fields of value can be boundless or infinitely dense in topological and measure-theoretic senses.[25]

The first proposition was that a connected plenum was a necessary condition for ethics. The second proposition was that fields enable a boundless multiplicity of potential dynamics. Now we can add a third proposition:

(3) Affective intensity constitutes value, and so is primordial (as substrate) to ethical action.

Care and Politics

Years ago, one of the students in my Interactive Design program wanted to create a web-based information system that would archive congressional records and make them available to the public as legislation was being proposed and shaped in committees. She reasoned that this would encourage public investment, intertwining public discourse with legislative discourse, and ultimately be a tool helping to reconstitute a more democratic *res politica*. This was predicated, like many great civil rights movements of the latter part of the twentieth century in the United States, on a certain assumption of *communicative rationality*, the Habermasian contention that human rationality is a necessary outcome of successful communication. The identity-based movements of the 1980s inherited the political logic of the successful civil rights movement a generation earlier and even managed to partially institutionalize recognition and power for certain disadvantaged identity groups. I have much sympathy with these movements. And I do not wish to debate the possibility and rational efficacy of "transparent" communication, because my concern lies at quite a different level. *Even if* I were able to gain a proper political place as a Chinese-American in the heterogeneous society, *even if* the glass ceilings were broken for women in the workplace, *even if* every harm against the Japanese-Americans in the United States during World War II were fully recognized and compensated, *even if* African-Americans were able to come into their own after slavery and its aftermath, *even if* the peoples of First Nations were able to live in the lands in the manner that they would wish, why should a member of one kind of people feel any solidarity with a member of another? Why should I care about you? *Care* is what I call the *affective field* primordial to collective politics (what used to be called solidarity), or more precisely, primordial to the vector fields of collective political power. (Here I use this word "field" particularly for its connotations in mathematics and physics as well as its colloquial sense of continuous variation in time and space, and its latent potential for powering movement and material change. Precise definitions will come in chapter 6.) It has nothing to do with charity, Christian or otherwise, because it exists prior to the institutions of power, whether secular or churchly. Nor is it identical with Heidegger's *care* as an existential attune-

ment of *Dasein* to the world. It is primordial in the way that Foucault's governmentality is primordial to the institution of the modern state.[26]

Care ⇔ recognition of fellowship.

However, this raises its own question: What underlies this implication?

Recall the example of palpation. Palpation has ethical and informative power because of a *textural resonance* between the physician and the patient. The textural refers not to pushing buttons or measuring predicates on a patient, but to the warmth, sureness, and continuity of movement, vocal as well as gestural. (I will elaborate on the textural later on.) Resonance is the concept bridging natality and care. It does not require isomorphism or telementationalist[27] transmission of objects, or the supposed transmission of abstractions such as "data" or "information." (In a deep sense, that is why it takes relatively negligible force or energy to make a large effect when rocking a car cupped in snow, if the force applied is synchronized to the cycle of the car's motion.)

Arendt's caritas ⇒ natality

To paraphrase Maurizio d'Entreves, *natality is the fact of having been born, introducing a new beginning in the world*. The later Arendt's description of natality substantially deepens her dissertation's approach to the problem of Augustinian care—"caritas"—against Heidegger's existential and thanatopic characterization of care.

Care, in my use of the term, is the pathic recognition of natality. This is considerably more special than the Heideggerian concept of care (*Sorge*) as attunement.[28]

(4) Care, an affective field, nuanced by attunement and pathic sensitivity, is primordial to politics.

Freedom and Poiesis

So, natality underwrites care as an affective field primordial to politics. Natality is also intricately related to freedom.

By freedom, I do not mean being able to make an unconditioned choice among options (think of the coffee shop example). Maurizio Passerin d'Entreves writes:

> [B]y freedom Arendt means the capacity to begin, to start something new, to do the unexpected, with which all human beings are endowed by virtue of being born. Action as the realization of freedom is therefore rooted in *natality*, in the fact that each birth represents a new beginning and the introduction of novelty in the world.
>
> To be sure, Arendt recognizes that all activities are in some way related to the phenomenon of natality, since both labor and work are necessary to create and preserve a world into which new human beings are constantly born. However, of the three activities, action is the one most closely connected with natality, because by acting individuals re-enact the miracle of beginning inherent in their birth. For Arendt, the beginning that each of us represents by virtue of being born is actualized every time we act, that is, every time we begin something new. As she puts it:

"the new beginning inherent in birth can make itself felt in the world only because the newcomer possesses the capacity of beginning something anew, that is, of acting."[29]

Freedom entails Kantian autonomy, i.e., independence from being determined by a rule-governed system. But Arendt extends this notion of freedom, in Miguel Vatter's interpretation:

> Freedom requires the automatism of life while remaining counter-natural, where "natural" means subsumed under a law-like process. Natality is the only category that satisfies both of these, apparently contradictory, conditions: belonging to life yet not subsumable under a rule or law (and hence "miraculous").[30]

In an essay on Arendt and natality, Vatter remarks that for Arendt, freedom has three essential features. First, it has a sense of the automatic, i.e., of not being subject to determination in a rule-governed system. Second, unlike Kant's noumenal conception of freedom, Arendt's freedom is thoroughly conditioned, phenomenalized, and therefore particularized to the individual life.[31] Third, and most importantly, he finds that Arendt links freedom not to Heidegger's being-toward-death but to natality: "Natality is the key category for a politics that is to come after the end of the nation-state, . . . after all attempts to [relate the] political . . . to the familial, and . . . after . . . all political form or organization as such."[32]

With regard to an Aristotelian distinction between *zoe* and *bios* (the category of living things versus the category of the human), one could align Arendt with Heidegger as being concerned primarily with *bios*. However, one need not accept this distinction so categorically, nor identify Arendt so hastily with Heidegger. As Vatter writes:

> Arendt's conception of natality does not presuppose the Aristotelian dualism between *zoe* and *bios*. . . . [N]atality is not only what "inserts" life into a pre-given world, but . . . is also what "daily renews" this world itself. . . . [N]atality is irreducible to the *bios politikos* . . . [and] a politicization of *zoe*, not of an always already "political" *bios*. This politicization of life goes in the opposite direction of . . . "the cycle of ghenos (descent, race)."[33]

I suggest that we can no longer afford to act insisting on this distinction between *zoe* and *bios* (as if we ever could). My point is somewhat stronger than where Vatter, and Arendt, may have been willing to go: if we are to hope for any understanding of how to live adequately to the world, we need to lift the political implications of natality from its anthropocentric cradle to include the energetic labor of *zoe* as well. And in so doing, to avoid the anthropocentric commitments in the concept of freedom, I prefer to think in terms not of freedom but of its *textural analog, poiesis*.

Texture

A parable: If you lay out tiles of glass on the ground in the cold, edges tightly butted together, over time, with the heat of the sun, they will expand and, because they have nowhere to go in their plane, will buckle and crack. So the next year, you learn to lay

them with gaps in between. If you nonetheless wish to make a continuous, smooth surface, you could fill the gaps with silicone or some other elastic material that bonds to the edges of the tiles, but gives and stretches under the expansion and contraction of the glass.

Another parable: The difference between a violin and a piano is nuance. A violinist can bend the pitch of a singing line of sound by varying the tension of the fingers on the strings and the bow at the same time. The infinite degree of variation possible yields nuance not only as pitch bend, but as vibrato, fatness, and *any number* of qualities. In fact there is no a priori set of mechanically distinct qualities, although by convention over the years violinists have developed an expert vocabulary for talking about how they nuance their musical sound. But the essential point is the possibility of *continuous* variation—nuance.

What nuance (the continuous dense variation of corporeal gesture in material substrate) affords is an infinite possibility of the fresh or singular, even at the textural level. In fact, it is the indefinitely fine that is the texture of freedom, which I will call, from now on, *poiesis*. This poiesis, like Arendt's freedom, is fully conditioned—textured, colored—by all the affective fields in play, fields that are in turn sensitive to the macrodynamics of history and politics, as well as mesodynamics of sexuality and power. However, the poiesis I propose differs radically from freedom in two respects: (1) it does not presume an anthropocentric subject, (2) it is textural, not oriented toward objects. We can ask what "coloring" implies in such a context. In the case of speech and languaging, Deleuze and Guattari write in *A Thousand Plateaus*: "[This chromaticization] *places the public language's system of variables in a state of variation* [emphasis original]. This is what we are getting at: a generalized chromaticism. Placing elements of any nature in continuous variation is an operation that will perhaps give rise to new distinctions."[34] We can understand chromaticization in fact as a mode of continuous variation through the dense substrate. Regarded from the perspective of the textural rather than the anthropocentric, chromaticization is a mode of the world in poietic ontogenesis, the subject of chapter 5. What is natality then, in the nonatomistic sense of substrate, but the fact of *fresh, textural singularity in the material exfoliation of the world, the textural condition of poiesis*? *Textural* means that it is an everywhere-dense subset of the world, in a sense that will be made precise in chapter 6. The subtle point here is that a plenist texture has a different order of continuity than a union of isolate points—a bag of dust versus a bag of water. The twentieth-century characterization of the density of the real line, the Dedekind cut—"between any two real numbers $a < b$ there exists a third real number c such that $a < c < b$"—is a test that applies to the continuum $\mathbb{R}$ (the so-called real line). But this test uses the peculiar unidimensionality of $\mathbb{R}$ and does not work in more general sets. For that we appeal to general point set topology and the notion of open set and open cover, to be developed in chapter 6.

I gather these thoughts into a fifth proposition:

(5) Continuity (in the space of variations of plenum) affords nuance and poiesis: the textural natality of material.

In my usage, to *afford* means to constitute the material conditions of possibility.

Some Implications

Let me trace these themes in three domains of expression: software programming, video, and bodies in movement. Why go to such a level of technical detail? One of the guiding challenges for this book is the motto "art all the way down." If we are going to experiment with how objects, tools, instruments, even gestures and techniques come into being, dissolve, and reform, then we need to pay attention to the materials from which they are made. So the microtexture, quasi-chemistry, and quasi-physics of the material itself as well as the macrosocial are all potential media for artful investigation, warranting the artful synthesis of visual, sonic, textile, and other material regarded as temporal media. Of course opening up the technical substrate for artful investigation may simply displace the schematizing power from one stratum of technology to another. To gain fine technical control of computational video, for example, requires a bubble of a lab funded to do that sort of work (chapter 7) and technical expertise in the lattices of knowledge (e.g., computational fluid dynamics and low-level coding for parallel machine architectures) significantly more disciplined than the craft typically available to DIY artists and hackers. However, the very same epistemic and technical disciplines that enable such powerful expressions equally powerfully hobble them.

Example 1: From Object-Oriented Programming to Real-Time Signal Processing

More than twenty years ago, a group of Xerox PARC researchers released the grandfather of object-oriented languages: SmallTalk.[35] Promoters of object-oriented programming (OOP) urge programmers to think about their world in terms of classes of "concrete" objects and relations between these classes. Of course these classes of objects, being software, are already stripped of most of the qualities of ordinary experience, yet the pedagogical examples often use comforting analogies to everyday categories like animals: a dolphin is a mammal is an animal; a giraffe is also a mammal. A giraffe is both a mammal and a land creature, therefore it inherits properties of both. A dolphin, on the other hand, only inherits properties of mammals. Each class of objects has certain functions (called methods) that allow other software objects to inspect or set its properties or invoke some action. For example, "eat" is a method (action) particularized to very different actual actions depending on the specific class of animal, but the method (action) eat could be performed by any member of a subclass of the class of animals. Also, the method "eat" is *polymorphic*: what dolphins eat (and how they eat it) differs in type from what cats eat. OOP, while comforting in its promise to allow programmers to write software isomorphic to any taxonomy of a subset of the world, also quickly developed as much complexity as the world itself,

and worse. The world comes to us ordered by generations of stories and myth, folk knowledge, and many other machines of memory, economy, and desire. But OOP taxonomies, being invented naively and instantaneously with respect to historical time, do not inherit such sense-making order. The community of OOP software engineers has compensated by inventing patterns[36] and frameworks that bundle programmers' folk knowledge about a coherent set of functionalities, usually quite mundane but intricate functions like printing or saving a file. As I pointed out, hierarchical structuring only defers the problem of complexity by one structural stratum. The contradiction is that to be useful in practical, commercial situations, OOP frameworks have to be as large and complex as the world they model, and they grow ever more complex over the years. But large frameworks typically become intelligible only to their authors. Any large OOP framework tends to challenge a novice programmer's ability to read and comprehend a complex hierarchy of interrelated classes. In fact, SmallTalk's authors elevated this to a virtue, saying that a good SmallTalk programmer reads more than he writes, a particularly dry simulacrum of scholasticism.

An Aside about Categories, Objects, and Morphisms

What lay beyond the Babel of OOP was the shimmer of *category theory*, which emerged in the 1940s, about twenty-five years before the emergence of SmallTalk and then the more statically schematized object-oriented language C++. The next pages describe category theory in some detail precisely so we may know something of what this book attempts to set aside.

A *category* is a collection of entities with some internal structure, with associations relating pairs of entities called *morphisms* that preserve structure. A basic axiom of categories is that morphisms can be composed: given a morphism f from object X to object Y, and a morphism g from object Y to object Z, there is a morphism called $g \circ f$ from object X to object Z. Usually, where the morphisms can be defined as mappings on elements of objects, this means that for every r in X, the mapping $g \circ f$: X $\rightarrow$ Z is defined by $g[f[r]]$, that is, apply f and then apply g (see figure 4.3).

Given two categories C, D of mathematical objects, and mappings between them, category theory defines a *functor* as a map carrying objects in C to objects in D, and

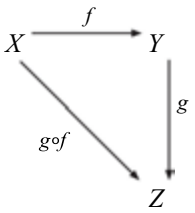


Figure 4.3
A composition of maps f and g among three objects X, Y, Z in a category. Diagram courtesy of author.

morphisms in C to morphisms in D. More precisely, if H is a functor from C to D, then for every morphism f: $X \to Y$ in C, $H[f]$ is a morphism $H[X] \to H[Y]$ in D. The two axioms that a functor must satisfy are that it respects identity morphisms and composition. More precisely:

(1) $H[\mathrm{id}_X] = H[\mathrm{id}_{H[X]}]$ for every object X in C, where an identity morphism on an object X maps every element of X to itself: $\mathrm{id}_X[s] = s$ for all s in X.
(2) $H[f \circ g] = H[f] \circ H[g]$ for any composition of two morphisms f: $X \to Y$, and g: $Y \to Z$ in C.

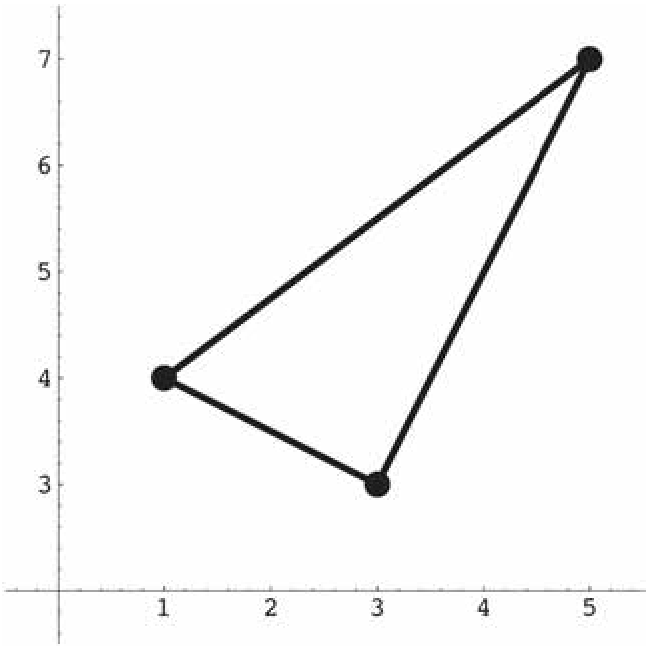
A student of mathematics first encountering object-oriented programming (OOP) with its emphasis on classes may be reminded of category theory, but it soon becomes clear that almost no functorial relations obtain. Although it may be theoretically interesting to make a formal category out of software frameworks, most working-class OOP engineers outside the largest engineering combines such as Hewlett-Packard and IBM do not try to make such structural-propositional homologies across OOP "ontologies."[37]

At the beginning of this chapter I said that my purpose is not to classify objects or their dual subjects, but rather to offer an approach to articulating objects as they come into being, as they emerge from continuous fields of media-material and then dissolve again into those fields. Category theory does not satisfy this in two fundamental ways. First, category theory is a *description*, not a mode of articulation of material. Indeed category theory is not a theory about a set of mathematical objects like manifolds or paths in a configuration space, but a theory about theories: a doubly abstract (in a logical and not Deleuzian sense of abstract) description about theories about families of mathematical objects. Second, category theory says nothing about the dynamics of physical, or living, affective material. For this, as we will see in chapter 6, we go to particular mathematics adapted to our purpose here, the dynamical articulation of material plena of matter, energy, and affect. Despite the enormous power afforded by category-theoretic methods to extend whole theories across vastly different domains of objects and their structurally indigenous mappings, mathematicians who favored more concrete ontologies nicknamed category theory "arrow theory," or "abstract nonsense."

One may try to justify an atomistic, object-oriented ontology by claiming a homomorphism of sorts between the "real world" of things and the objects in an object-oriented programming language via the formalisms of category theory. However, the existence of such a framework does not imply that there is a natural functor between phenomenon and representation.

Example 2: Drawing, OO Graphics, Video as Picture, Video as Light

An object-oriented drawing application like the canonical MacDraw or Adobe's Illustrator provides a small set of atomic geometric shapes that can be combined or modified as algebraically independent objects. "Algebraic" in this case means there is a finite discrete set of primitive objects, for example {*circle*, *square*, *line segment*, *triangle*};




```
In[1]:= Vertex1 = {3,3}; Vertex2 = {5,7};   Vertex3 = {1,4};
In[4]:= Triangle := {Vertex1, Vertex2, Vertex3, Vertex1};
In[5]:=  Show[
  Graphics[{{Thickness[0.01],Line[Triangle]},{RGBColor[0,0,0],PointSize[0.04],
        \Point[Vertex1], Point[Vertex2],Point[Vertex3]}}],
        Axes\[Rule] True, AxesOrigin\[Rule]{0,2}, PlotRange\[Rule]{{-0.5,5.5},{1.5,7.5}},
        AspectRatio\[Rule]Automatic
  ]
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Figure 4.4

Three representations of a triangle: a relatively semantically rich description as geometric primitives, and a semantically shallow bitmap.

every object comes with a notion of inverse: for example, *create-a-square*, *delete-a-square*; and objects may be combined with some uniform operation: for example *place-in-view-at-cursor.* By contrast, a bitmap drawing program, such as MacPaint or Photoshop, has no primitive set of macroscopic objects, and therefore makes no "object-oriented" restrictions on what the user can draw. This freedom for sketching comes at the cost of having the program *not* maintain extra information about specific classes of geometric objects on behalf of the person who sketches, such as the fact that there are exactly three vertices defining any triangle, so information for three points is maintained somewhere in the machine representation, with the rendering of the triangle always interpreted as joining the three vertices by three straight line segments. However, when Joan Miró draws (and we see) a "triangle" in his painting *Circus Horse* (1927), it is not any triangle that the object-oriented program would have recognized or given to him as a primitive. Even more allusively, in Miró's *Person Throwing Stone at Bird* (1926; figure 4.5), the humorous point of the scene is the hopeless

Figure 4.5
Joan Miró, *Person Throwing Stone at Bird*, 1926.

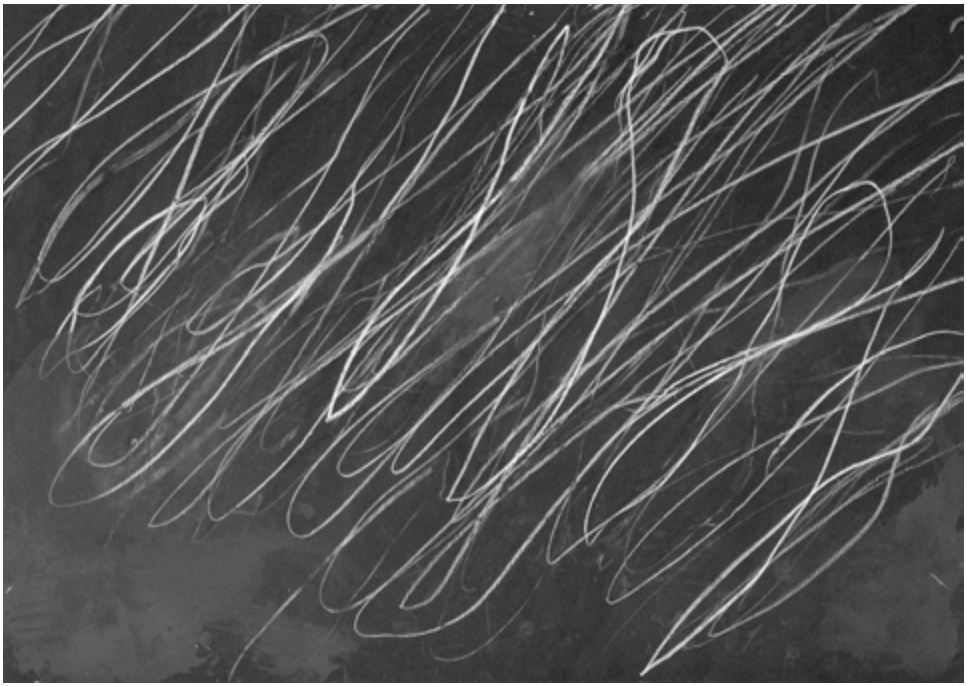

Figure 4.6
Cy Twombly, *Untitled*, 1970, one of a series of blackboard drawings.

inadequacy of the arc despite its perfect circularity, whose radius—its dashing connotes the hunter's calculating intent—is mocked by the radius of the bird's body. None of this is coded in the drawing program's geometric representation.

One might object that even a bitmap is a machine representation of visual pattern (see figure 4.4). The difference is that the encoding in terms of "geometric" labels like vertex and triangle presumes we are capturing essential meaning with these labels. But we can see that even the most preliminary reading of Miró can activate much sense exceeding the descriptive reach of either kind of machine representation. And elaborating some machine-codable schema to faithfully represent the affective dynamic and implications of the painting would be as pointless as making a chess program to enjoy a game of chess on our behalf.

And there we see the point: Why not leave the interpretation to the participant at the moment of the event, to the one who makes the brush stroke at the moment of making that stroke, or the one who makes the affective interpretation at the moment of encountering the painted canvas (see figure 4.5)?

Going to 3D graphics only obscures the issue. The basic mistake is to identify geometry with the visible, when in fact most of what modern differential geometers

Figure 4.7
Calligraphic video (A) as image, and (B) as structured light.

imagine has very little to do with the pretty images that a computer graphics program can provide.

The standard abstractions of object-oriented graphic models in computer graphics codified in industry-standard 3D representation and rendering frameworks, such as Maya, Renderman, and OpenGL, have built up as an enormous body of algorithms and hardware mostly predicated on the construction and drawing of polyhedral surfaces in three-dimensional Euclidean $\mathbb{R}^3$. Historically, the resulting images typically suffered from a deadness, a lack of breath. All the sophistication in the modeling of geometrical optics and optics of material surfaces could not escape the fundamental misstep, which was the obsession with polygons rather than continuous stroke and gesture. (A major alternative graphic representation system—PostScript—admitted abstract representations of polynomial curves that could be rendered at arbitrary physical resolution, because, being a printer specification language, PostScript could defer conversion to particular pixel representations till very late in the process of printing on their target devices: paper printers. One of the principal innovations of the NeXTStep operating system—the precursor to Apple's OS X—was using PostScript as its underlying drawing language, which permitted arbitrary scaling of its screen graphics.) This changed in the last decade when cheap memory and speedier CPUs finally permitted the "interactive" manipulation of bitmaps, in fact, of textures mapped onto (sufficiently fine polyhedral approximations of) continuous surfaces.

Instead of slinging polyhedral geometries in OpenGL, I reasoned differently:

1. Ultimately, however sophisticated and arduous the processing, the image is still to be displayed on planar two-dimensional surfaces, whether on computer display monitors, plasma screens, or projectors beaming images onto flat planar screens. So why

not conserve CPU cycles and concentrate processing power on just two-dimensional data throughout the input and resynthesis pipeline?
2. A sure way to generate credibly rich texture is to acquire imagery directly from the world in its full density by "sampling" video or sound. Even surer is to skip the step of digitization and allow the participant to physically manipulate material.

Exercise: Take a brush. Dip it into ink. Drag it fast, then slow, across rice paper. Use a wet brush, a dry brush. Notice the corporeal, physical effects lost in translation to digital tools and screen-based displays.

Exercise: Take a lump of dough (or clay). Knead it. Press it flat. Try to roll it out. (Clay has memory, dough *develops* memory.)

Richness ⇔ Continuity. In fact the continuity is what affords expressive shaping.

This motivated the work of the Topological Media Lab on synthesizing video as textures responding to contingent gesture: "calligraphic video," accompanied by analogous "gestural sound." We typically regard video, whether it appears on a computer display or projected on a wall, as image—depicting a picture *of* something. But substituting a small projector for a light bulb gives us the opportunity to regard video as *structured light dynamically illuminating a physical space instead of the projection of an image*.

Together with physical materials such as the sonically responsive textiles woven with conductive fibers, dynamical media textures—*temporal textures*, dense fields of variations in the tempo and rhythm—constitute the raw material with which we construct our responsive environments.

Regarding and synthesizing video as a painterly or calligraphic rather than an object-oriented or typographic medium implies that we dispense with syntax composed of predetermined, discrete classes of gesture yielding predetermined, discrete classes of graphical objects. Of course, definite techniques (orthographies) of movement and corporeal and thoughtful comportment have evolved over historical time, but the implement can condition rather than rigidly enforce specific sequences of movement. In fact, among "analog" drawing instruments, more hypostatically designed instruments with rigid action tend to have very narrow and limited use before being abandoned in favor of "simple" tools like brush, pen, charcoal, and corresponding "syntax-free" drawing surfaces. There is no right stroke or wrong stroke; every movement of the hand makes a mark of some sort depending on the microphysics of the implement, the coloring substance, and the substance of the drawing surface.

To the extent that the goal is to produce 2D images on a flat surface like a display or a wall, this version of *calligraphic video* suffices. But there can be a more ambitious aspiration: to make structured light with sufficiently powerful projectors. *Calligraphic video* (1) treats video not as image but as structured illumination, and (2) creates palpable light fields, leveraging corporeal experience.[38]

My strategy has been to leverage the intuition sedimented into our bodies over a lifetime from birth—more than a lifetime if we include the corporeal disciplines in which we're schooled: playing music, playing sport, uttering language, and so forth. In order to manipulate or navigate or shape light (and image as texture), if we wish to use structured light for its palpable interference with dynamical matter, what better way than to make it respond to individual or collective gesture as a physical material would respond? Why physical material rather than logical statements, or cultural code (logos, branding, fashion, design)? We appeal to physical matter because we acquire from birth a lifetime of experience with the felt sense of matter around us, a condensation of felt experience prior to language, spoken or written. Why computational media (matter)? Why not stick to physical, noncomputational matter? With computational media, we can create media/matter that is modeled after physical matter and can be approached or manipulated with some corporeal intuition, but that behaves in a *quasi-physical* manner like and unlike familiar sorts of physical matter. Computationally modulated material textures can constitute the experimental medium (not just the trope of "apparatus" inherited from nineteenth-century science) for propositional, speculative essays in fields of gesture and movement.

This détourned matter can be a substrate bearing marvelous symbolic charge.

I envisioned the TGarden as a responsive environment so thick with media that it is not obvious where the body ends and the rest of the world begins. One way is to suffuse the environment with responsive light whose temporal textures fluctuate concurrently in concert with the movement of bodies in the same space.

Example 3: From Bodies in Movement to Bodies from Movement

In computer graphics, presently the best physics engines for games can handle tens of thousands of mutually interacting particles before giving up the ghost, but even twenty years ago physicists were writing special applications to simulate the movements of 100,000 to 1,000,000 stars by treating them as mass densities distributed continuously across space, rather than as individual particles. In 1911, Plummer invited a "softening" technique that replaced the dynamics of particles with the dynamics of fluids. In fact, the most recent work by Mori and Umemura is a good example of using hydrodynamical equations to articulate the physical processes in a galaxy colliding with another. There is always a contest between simulating discrete particles and simulating continuous distributions of matter. Each can be derived from the other.

Conjuring Bodies—Not as Metaphor but as Fact of Matter

Every time we slip on a shirt, we slip on a second skin. Every time we speak through a cell phone we speak in another voice and scatter ourselves in ether. Every time we massage oils and electromagnetics into a body, we make it porous, sometimes with

seductively perilous effect. But where does the body end and the world begin? What does it mean to move, to embody, to be moved? What becomes of bodies, persons, and subjects when we take our drugs, our computers, and our nano-toys from the same needle? In fact, what becomes of our bodies and our selves when computers, biotech, and nanotech are woven into the very fabric of our built world? We conventionally think of the body making gestures, but how can we imagine gestures making a body? As microcameras and sensors and sensate or luminous materials become ubiquitous, the space itself between us becomes a sensing and kinetic tissue that extends our expressive bodies. How can wearable, responsive textiles and temporally textured fields of sound and light trace and transmit playful gesture?

The Topological Media Lab has worked since 2002 with active—sensate, emissive, kinetic—fabrics, wireless sensors, wearable synthesized sound and image, to present works responding to these questions. The interventions have ranged from scientific research on basic gesture and the engineering of wireless sensor platforms, to parodies of the implausible logics of the fashion shows in electronics trade conventions, to instances of performative art. (Again, by "performative art" I refer to events constructed in which all the participants are equally performing as well as spectating agents.)

Often, however, performance works assume we know what a body is, where a body ends and the world begins, what we mean by being embodied, by movement, affect, emotion. But technologies like medical imaging, endoscopic surgery, bioelectronic prostheses, wireless sensors, and fabrics that can sense, display images, and move are thickening the world between the skin and the walls of the city, between what we called self and nonself.

What becomes of bodies, persons, subjects, and subject positions when computational and biotechnical or nanotechnical mediation becomes so thoroughly dispersed into the fabric of our built world? What about desire or agency, human and nonhuman? To pursue this more rigorously, we can turn to topological media and dynamical processes (on manifolds).

Having said all this, nonetheless, I should respond to the would-be objector that of course objects and categories exist. My concern is not to deny that they exist but to understand how they come to be and how they pass on. Can we construe the object in a way that (1) accommodates change, (2) spans all ontological strata as Guattari envisioned them, and (3) accommodates nonanthropocentric subjectivation?

Consider, for example, in creating real-time sound accompanying a dancer's movement, the difference between motion capture or body tracking and sound as a responsive texture. Expressed as a circle of real-time media processing (which seems to the human performer simultaneous with her or his movement), this includes: (1) processing the signal from the moving body (via any sensors, cameras, etc.); (2) modeling location or body shape, i.e., geometric models; (3) parametrizing sound synthesis

models (e.g., in MSP); (4) gesturally improvising with sonic textures. In our practical work, we have created richly articulable media without building high-level metric models such as anatomical skeletons for human movement.

Consider these three examples of what a *substrate* perspective yields in the domain of working with movement and responsive media:

(1) Instead of modeling for example the center of gravity—a point location—or joint angles or some other geometric information about the body, consider processes that respond to the entire play of light and dark across the camera's field of view. This can disregard the identity or point location of "bodies." In TGarden, this indifference to identity and constancy of body (via point location) permitted the playful exchange of "wings."
(2) Instead of tracking gaze, just make sound as a function of angle or Hausdorff distance between blobs. Then shadows can become ad hoc instruments, props constructed or, better, ascribed with use in the moment of performance. In play, shadow can transmute from a negative absence of (projected) object to become a positive thing.
(3) A more subtle example is the transfer from support to supported in a contact improvisation dance exercise, which the two dancers (or two parts of a mover's body) can feel. However, this transmutation of the balance of force may be essentially *indiscernible* to an optical sensor, such as a video camera.

An Object Is an Invariant (of a Lie Group)

Earlier in this chapter, we explored two large sets of challenges problematizing the notion of object and object-oriented ontologies: formal complexity and ethico-aesthetic adequacy. As I have said, I do not question the existence of objects or of their roles in social and technical practices. Instead, I suggest a complementary orientation to the emergence, formation, and transformation of objects.

Take this cup in your hand. Seen from above it is a disk. Seen from the side it is a rectangle, with a semicircle attached. So the apparent shape is not what makes the cup the cup. When you see it from all angles, what is the essence of this cup? Not the shape, apparently. Take this orange in your hand. What color is it? Walk with it underneath a green light and what will you say? "Orange," of course. But what would a spectral analyzer read? The orange would appear nearly black, because it reflects orange frequencies and absorbs the complementary frequencies of light, namely green. Seen under lamps with different spectra, this piece of fruit would reflect light with different spectra. So what makes an orange an orange is not its color, apparently. Consider this person. These are the first exercises toward a phenomenological investigation, enormously elaborated since Husserl and Heidegger.[39] But here I stop, because

we will take a different branch. While it will be extremely useful to be able to apply phenomenology's "transcendental reduction," where we part from phenomenology is where it presumes the ego cogitans, centering questions of experience on the *Dasein*, which is concerned irreducibly with (human) subjectivity.

Alain Connes, Fields medalist and one of the masters of noncommutative geometry, speculated in a conversation with Jean-Pierre Changeux[40] that objects of consciousness could be explained as topological invariants of some sort. This speculation, however informal, struck a chord with me, but of course such fancy leaves mysteries in its wake. What sort of invariant do we mean here? In what topological space live these invariants, and under what action?

Jean Petitot, following Husserl, develops a mathematical "model" for progressive aperspectivalization (a technique of eidetic variation) which converges on a limiting object. But the substrate need not, and perhaps (if we examine it carefully with the same optics that expose the cracks in naive realism) cannot, be neural matter or merely neural processing. Why not? One reason is that even dust under gravity or mud and gravel diffusing under water can aggregate themselves into objects. Petitot's ontological project lends substance to this claim, and we shall examine it more closely, after preparing the ground to understand it.