The N
Mater

In the last few decades an entirely new conception of the material world has emerged. Here, philosopher **Manuel DeLanda**, whose work has become synonymous with this ‘new materialism’, introduces this novel understanding of materiality. Like any other conceptual framework, it has precedents in the history of philosophy – the work of the Dutch philosopher Baruch Spinoza is a good example – but only recently has it become coherently articulated with science and technology. Gone is the Aristotelian view that matter is an inert receptacle for forms that come from the outside (transcendent essences), as well as the Newtonian view in which an obedient materiality simply follows general laws and owes all its powers to those transcendent laws. In place of this, we can now conceptualise an active matter endowed with its own tendencies and capacities, engaged in its own divergent, open-ended evolution, animated from within by immanent patterns of being and becoming.

The new vision of the nature of materiality has been made possible by a series of changes to older concepts. Some were improved or refined, like the concept of causality, while others were radically transformed, such as the idea of an eternal and immutable law that mutated into that of distribution singularities. The old conception of causality – the production of one event by another[1] – was inherently linear. The formula for linear causality is 'same cause, same effect, always'. From this, naive forms of determinism ensue: if every cause always has the same effect we should be able to follow the chain all the way to a first cause, and vice versa. So once that first cause occurs everything else is given: there is no novelty in the universe. But the different assumptions built into this formula can be challenged to produce different forms of nonlinear causality. The word 'same', for example, can be challenged in two ways because it may be interpreted as referring both to the intensity of the cause ('same intensity of cause, same intensity of effect') as well as to the very identity of the cause. The simplest departure from linear causality is that which challenges sameness of intensity. As an example we can use Hooke's law, which captures a regularity in the way solid bodies respond to loads, like a strip of metal on which a given weight has been attached. Hooke's law may be presented in graphic form as a plot of load versus deformation, a plot that has the form of a straight line (explaining one source of the meaning of the term 'linear'). This linear pattern captures the fact that if we double the amount of weight supported by the metal, its deformation will also double. More generally, Hooke's law states that a material under a given load will stretch or contract by a given amount that is always proportional to the load.

While some materials, like mild steel and other industrially homogenised metals, do indeed exhibit this kind of proportional effect, many others do not. Organic tissue, for example, displays a J-shaped curve when load is plotted against deformation. A gentle tug of one's lip, for instance, produces considerable extension, but after that, pulling it harder causes little additional extension. In other words, a cause of low intensity produces a relatively high-intensity effect up to a point, after which increasing the intensity of the cause produces only a low-intensity effect. Other materials, like the rubber in a balloon, display an S-shaped curve representing a more complex relation between intensities: at first increasing the intensity of the cause produces almost no effect at all, as when one begins to inflate a balloon and the latter refuses to bulge. As the intensity increases, however, a point is reached at which the rubber balloon suddenly yields to the pressure of the air, rapidly increasing in size, but only up to a second point at which it again stops responding to the load.

The fact that the J-shaped and S-shaped curves are only two of several possible departures from strict proportionality implies that the terms 'linear' and 'nonlinear' are not a dichotomy. Nonlinear patterns represent a variety of possibilities of which the linear case is but a limiting one. A stronger form of nonlinear causality is exemplified by cases that challenge the very identity of causes and effects in the 'same cause, same effect, always' formula. When an external stimulus acts on an organism, like a simple bacterium, in many cases it is a mere catalyst. A biological creature is defined internally by many complex series of events, some of which close on themselves forming a causal loop (like a metabolic cycle) exhibiting its own internal states of stability. A switch from one stable state to another can be triggered by a variety of stimuli. Thus, in such a system different causes can lead to the same effect. For similar reasons two different components of a biological entity, each with a different set of internal states, may react completely differently to external stimulation. That is, the same cause can lead to different effects depending on the part of the organism it acts upon, like a hormone that stimulates growth if applied to the tips of a plant, but inhibits it if applied to the roots.

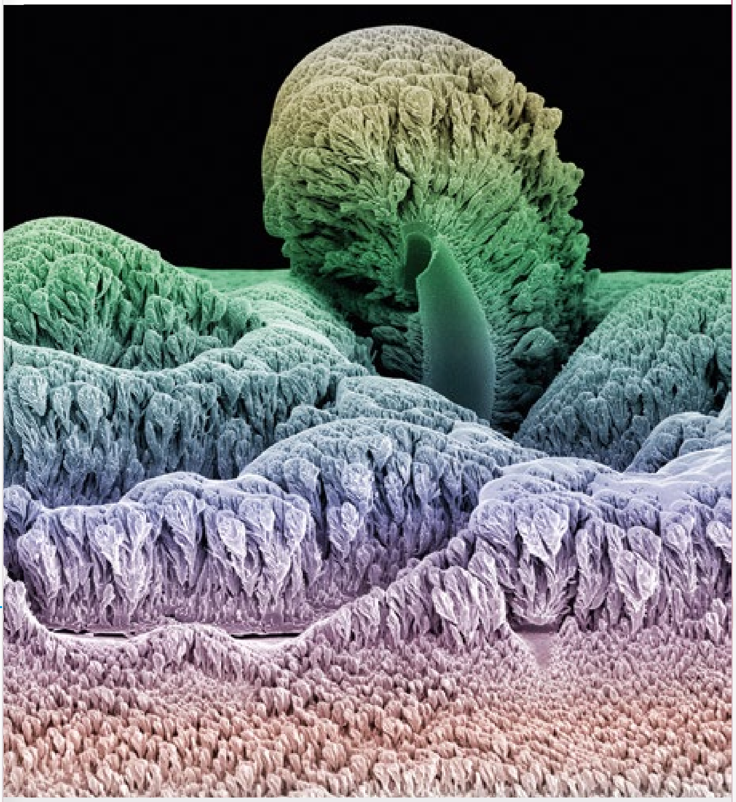
Conceptually, the switch from linear to nonlinear causality involves taking into account not only an entity's capacity to affect (a load's ability to push or pull), but also another entity's capacity to be affected (a particular material's disposition to be pushed or pulled). Whereas in Hooke's law only the load's capacity to affect is considered, once we switch to organic tissue or rubber, their different capacities to be affected need to be included. And in the case of catalysis, the internal states of an organism define capacities to be affected that can be triggered by stimuli with very different capacities to affect. Thus, an important conceptual move in the direction of an active materiality is the characterisation of material systems not just by their properties, but also by their capacities. This can be illustrated with a simple example. A knife is partly defined by its properties, such as having a certain shape or weight, as well as being in a certain state, like that of being sharp. A sharp knife, on the other hand, has the capacity to cut things, which can be exercised by interacting with entities that have the capacity to be cut: cheese or bread, for example, but not a solid piece of titanium. Philosophically, there is an important distinction between properties and capacities. Properties are always actual, since at any given point in time the knife is either sharp or it is not. But the causal capacity to cut is not necessarily actual if the knife is not currently being used. This implies that capacities can be real without being actual. The technical term for this ontological condition is 'virtual'. This double life of material systems, always actual and virtual, has been emphasised by contemporary materialist philosophers such as Gilles Deleuze:

Calcium carbonate
False-coloured SEM of microscopic calcium carbonate crystals. Calcium carbonate has many polymorphic (different-shaped) crystal forms. The spherical crystals are termed 'vaterite', and are made up of many hexagonal vaterite plates, arranged in 'rosettes' in this image. Calcium carbonate occurs naturally in many rocks such as limestone and chalk, and is relatively inexpensive to extract. It has a multitude of different industrial uses and is the most common active ingredient in antacid tablets.

> The virtual is not opposed to the real but to the actual. The virtual is fully real in so far as it is virtual … 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 … 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.[2]

In addition to asserting the double life of all material entities, their simultaneous actuality and virtuality, the previous quote suggests a solution to the problem of the kind of existence constituted by the virtual: its reality is defined by the structure formed by differential elements and distributions of singularities. To make things easier in defining these terms, we can take a simpler case than that of capacities: material tendencies, such as the tendency of a substance to change from solid to liquid, or from liquid to gas, at certain critical thresholds. Most of the time these tendencies are virtual or potential, becoming actual only when a substance is actually melting or vaporising. But the number of possible states that matter can tend to is typically finite, whereas the number of actions of which it is capable is not: the same knife that has the capacity to cut can acquire the capacity to kill if interacting with an animal, or the capacity to murder if interacting with a human being. In either case, we are dealing with spaces of possibilities, finite spaces in the case of tendencies, open-ended spaces in the case of capacities, but the former are much more accessible to rigorous formal study.

The first concept in the definition of the virtual is 'structure', and we can now be more specific about it: the structure in question is the structure of a possibility space. It is this structure, given in the case of the tendencies just mentioned by the critical thresholds of melting and vaporisation, which has a reality beyond the actual. These critical thresholds are one example of a distribution of singularities, the term 'singular' meaning remarkable or non-ordinary, a special event in which a change in quantity becomes a change in quality. The possibility space in this instance has as many dimensions as there are parameters affecting the substance: if only temperature changes, then the space is one-dimensional (a line of values) and the singularities are points (freezing and boiling points); if temperature and pressure both change,



Tungsten
Coloured scanning electron micrograph (SEM) of tungsten metal crystals, called a tungsten forest, coating the inside of the SEM's electron gun. The energy of the beam of electrons produced by the gun is so powerful that it evaporates the tungsten metal, which then cools and crystallises on the inner surface of the gun's chamber.

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the space is two-dimensional and the singularities are lines; and if we add specific volume as a third parameter, the space is three-dimensional and the singularities are surfaces. In general, in these phase diagrams singularities are always N-1, with N being the number of dimensions. This is important, because in the history of philosophy transcendent spaces are always one dimension higher (N+1), so the fact that the structure of a possibility space is N-1 is a sign of its immanence.[3]

Freezing and boiling points are not, of course, the only examples of singularities. When discussing catalysis above, we said that organic entities tend to possess a variety of stable states, and that they can switch from one state to another stimulated by a variety of causes. These stable states are also singularities. The state in which an organism happens to be at any one moment is actual, while all the other available states are virtual, waiting to be triggered into actuality by a catalyst. Given that these internal stable states also tend to be finite, they are also amenable to formal analysis. In this case, the first thing that needs to be done is to figure out the number of different ways in which the material system to be modelled is free to change. These 'degrees of freedom', as they are called, must be picked carefully: they must be the most significant ways of changing, since any material system can change in an infinite number of trivial ways. The degrees of freedom, in turn, must be related to one another using the differential calculus, that is, the branch of mathematics dealing with rates of change, or to put it differently, dealing with the rapidity or slowness with which properties can change. In the geometric approach to the calculus, each degree of freedom becomes one dimension of a possibility space, the space of possible states for the system, while the differential relations between them determine a certain distribution of singularities.[4] Here too, the N-1 rule applies: there are zero-dimensional singularities (point attractors), as well as one-dimensional ones wrapped into a loop (periodic attractors). In a space of two dimensions, that is all the variety that exists. In state spaces with three dimensions, however, attractors of higher dimensionality can exist, but as it happens they are not exactly two-dimensional: they have a fractal dimension (intermediate between one and two) and are referred to as 'chaotic attractors'.[5]

The tendencies towards different types of stability (steady, cyclic, turbulent) predicted to exist by this mathematical approach have indeed been confirmed in laboratory experiments. Soap bubbles and crystals, for example, acquire their stable shapes by the fact that the process that produces them has a tendency towards a steady state, the state that minimises surface energy or bonding energy respectively. Similarly, the periodic circulatory patterns that characterise certain wind currents (like the trade winds or the monsoon) and the underground lava flows that drive plate tectonics, are explained by the existence of a tendency towards a stable periodic state. The fact that the same singularity (a point, a loop) can structure the possibility spaces of physical processes that are so different in detail implies that the explanatory role of singularities is different from that of causes. The latter involve specific mechanisms that produce specific effects, and these mechanisms vary from one type of process to another. But underneath these mechanisms there is the same tendency to minimise some quantity (or to cycle through the same set of states over and over), and this shows that the singularities themselves are mechanism-independent. To explain the creative behaviour of any material system we normally need both a description of a mechanism that explains how the system was produced, and a description of the structure of its possibility space that accounts for its preferred stable states, as well as its transitions from quantitative to qualitative change.

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To conclude, linear causality and its necessary and unique outcomes give us a picture of matter as something incapable of giving birth to form by itself. In this old view, morphogenesis can only take place if an external agency acts on inert matter, either by incarnating an essence (formal cause) or by forcing it to acquire a form (efficient cause.) A richer conception of causality linked to the notion of the structure of a possibility space gives us the means to start thinking about matter as possessing morphogenetic powers of its own. In addition, the fact that a virtual structure can be actualised by different material systems provides us with a way to think about recurring regularities in the birth of form without having to invoke eternal natural laws. A material world in which transcendence has been exorcised and in which immanent morphogenetic powers supply the means for true novelty and creation, is the kind of world worthwhile being a realist about. AD

Notes

1. Mario Bunge, *Causality and Modern Science*, Dover (New York), 1979, p 156.
2. Gilles Deleuze, *Difference and Repetition*, Columbia University Press (New York), 1994, pp 208–9.
3. Manuel DeLanda, 'Intensive and Extensive Cartographies', *Deleuze: History and Science*, Atropos Press (New York), 2010, p 123.
4. Ian Stewart, *Does God Play Dice?: The Mathematics of Chaos*, Basil Blackwell (Oxford), 1989, pp 84–94.
5. *Ibid*, pp 107–10.

Phytokarst rock formation
This type of karst rock formation is created in areas of limestone caves where sunlight is present. The rock is eaten away by bacteria, leaving behind sharp spikes that angle towards the daylight, as seen here in a cave in Gunung Mulu National Park, in Sarawak, the Malaysian part of the island of Borneo.