Critical Events

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Catastrophes are critical events. When the word "critical" is applied to events it has a different meaning than when predicated of thinking: a critical situation is one that is dangerous, risky, uncertain, in the balance. This implies a combination of subjective and objective factors. On one hand, for the situation to be truly critical, for something real to be in the balance, the situation must pose an objective danger to the integrity of our bodies, our communities, and our cities. This objectivity can in many cases be determined by the intensity of the event, or more exactly, by the fact that this intensity has reached a threshold marking a sharp discontinuity in the behaviour of natural or artificial entities that have the capacity to affect us. On the other hand, the beliefs that people form about the risks involved, and the emotional charge of these beliefs, point to another type of intensity: not the intensities of temperature, pressure, or speed characterizing the critical event itself but the intensity of uncertainty and fear about its potential dangers. The abruptness of the discontinuity at the birth of the critical event only raises the subjective intensities higher, since we cannot respond using our trusty routines when a situation is far from ordinary.

Sometimes, the other meanings of the word "critical" converge in situations characterized by high objective and subjective intensities. A powerful event like hurricane Katrina revealed to a large number of observers many inequalities and incompetence: that in the distribution of private land in New Orleans physical height and income levels were correlated, so that low-lying poor neighbourhoods would of necessity bear the brunt of a flood because water always seeks the lowest level; or that the forced union of bureaucracies engaged in emergency response and national security created a dysfunctional agency with a diminished capacity to respond in a crisis. Although these two conditions could have been obvious to critical thinkers before the event, the hurricane itself made them visible to everyone, and in that sense the event itself was critical in the awareness of passing denunciatory or censorious "judgment" on the conditions prevailing both at the local and national level. Bureaucracies are tested by critical events in much the same way that people are. A person may display (or fail to) character only in situations that are problematic, that is, when the consequences of personal action cannot be predicted.

Those situations also demand a display of personal abilities to cope. In the case of institutions or organizations (public or private) there is a similar relation except that a failure to display character or ability has repercussions that go beyond a damaged personal reputation: the very legitimacy of the authority of an organization is at stake during a critical event. This is the objective side of the event impinging on its subjective (personal or organizational) side. But the opposite effect can also take place. Because the risks or dangers posed by a critical event are assessed by the formation of beliefs, and because these may vary in the degree to which they capture the reality of the situation, and may be more or less tinged by intense fear and anger, these beliefs can be manipulated. The perfect example in our time is September 11, a critical event that was exploited for all its political capital by an administration that possessed neither character nor ability, but that was nevertheless able to use the event as a source of legitimacy for a variety of actions, from going to war to passing tough new domestic surveillance laws. In what follows I will concentrate on the objective side of critical events.

This implies not only that subjective intensities will not be considered, but also that the objective intensities involved will not be necessarily scaled to human proportions. For a critical event to constitute a human catastrophe the amount of matter and energy mobilized during the event must be large enough to actually confront human beings with a life-and-death situation: a volcano must not just erupt but eject enough lava and ashes; a hurricane or tsunami must not just form but forcefully collide with coastal communities; and, of course, a small plane crashing against a skyscraper need not constitute a catastrophe, but a large one loaded with flammable fluid certainly will. But the objective features that characterize critical events, such as the abrupt transition from one state to another when a threshold of intensity is reached, are displayed by small and large events.

Small critical events are still catastrophes, only not human catastrophes. Catastrophe theory is one of several fields of mathematics that concerns itself with sudden discontinuous behaviour. Unlike the mathematics of classical physics that was tailored to smoothly changing, continuous series of events, this field attempts to capture not just quantitative but also qualitative change.[1] There are many examples of changes from quantity to quality in natural processes but one stands out for its ubiquity: phase transitions. The phenomenon of liquid water abruptly turning into ice or steam when temperature or pressure reaches a critical threshold is only the most familiar one. Less familiar illustrations are the change in the manner of flowing of any fluid as its speed reaches a threshold, going from smooth to wavy and then

[1] Alexander Woodcock and Monte Davis. Catastrophe Theory. (E.P. Dutton, New York, 1978), p. 2.

to turbulent; or the change in the gait of a moving animal as its speed increases, forcing it to go from walking to trotting, or even to break into a gallop. The larger scale critical events that constitute human catastrophes are in many cases based on these smaller ones. The thunderstorms that give birth to the tornados that cause so much damage every year, are formed by the coupling of two phase transitions: the one that gives rise to wavy or convective flow—a typical thunderstorm possessing five to eight convection cells—and the one that, by turning steam into water droplets, liberates the energy that allows the amplification of convection cells until they reach several kilometres in diameter. Thus, the study of the featu es of critical events at scales that would not be problematic for human beings may be necessary to study the features of those that are. Catastrophe theory concentrates on a particular type of critical event: abrupt qualitative changes in processes driven by a single gradient or potential. A gradient is constituted by a difference in intensity, like two masses of air or water at different temperatures, pressures, or speeds. When two such masses come into contact the whole they form constitutes a reservoir of potential energy, a reservoir that may be used to drive another process. The meteorological maps familiar to viewers of television news, with their zones of high and low pressure, and their cold and warm fronts, are a good illustration of how mobile gradients give the atmosphere its capacity to generate entities like thunderstorms or hurricanes. But the same gradients are also what drives many industrial processes: the steam engines behind the Industrial Revolution made use of temperature and pressure differences in much the same way that hurricanes do. Elementary catastrophe theory restricts itself to systems that are driven by a single gradient and that are affected by no more than four different causal factors.[2] Many processes, particularly in biology, are driven by more than one gradient, and involve more than four factors, so these must be studied either by extensions of the elementary theory, or by other related fields (like bifurcation theory). Nevertheless, the philosophically important features are already displayed in the elementary theory so we can confine our attention to this case. The most important insight is that, for the narrow class of processes tackled by the theory, there are only seven different ways for discontinuous behaviour to take place. There are, in fact, an infinite number of ways in which discontinuities can happen, but it can be shown that the majority of these collapses into the seven structurally stable ones when faced with even minor fluctuations. Since the world is always filled with small fluctuations of many types, and since these cannot be eliminated, unstable ways of undergoing qualitative change will tend not occur in reality. This means that the

[2] Ibid. p. 42.

stable ones constitute, in effect, seven different universal patterns for catastrophes. (Again, seven within the narrow class being modelled. When we add a fifth causal factor, for example, four other universal patterns must be added).[3] The reason these patterns are called “universal” is that catastrophe theory says nothing about the mechanisms behind the processes in which qualitative discontinuities occur: it demands that the process be driven by a gradient but this can be any reservoir of potential energy (electrical, thermal, gravitational, chemical); and it demands that the causal factors number only four, but does not specify the nature of the causes. This implies that many different processes, embodying entirely different causal mechanisms, can display similar behaviour when critical events take place.

The indifference on the part of the patterns to the causal details is what raises the expectation that catastrophe theory can be applied in many different fields. It has been used, for example, to model the threshold of discontent that can trigger a prison riot, although such social applications remain controversial.[4] For the same reason it could be used to model psychological events like the intense grief or sadness that can push a person to the breaking point, unable to recover after the deep loss and never being the same person again. Any actual human catastrophe, like that on the wake of Katrina, involves critical events of all these different types: the natural disaster of the collision of the hurricane with New Orleans; the engineering debacle constituted by the breeching of the levees; the breaking of social order that transformed some communities into looting mobs; the psychological impact on individuals, some of whom left the city broken, bowing never to return. And then, of course, the organizational failure and the resulting loss of legitimacy of the authority of the bureaucracies involved, a legitimacy they won’t recover until another critical event gives them the opportunity to display character and ability. The philosopher of science Michel Serres is the theorist who has made the most out of the universality of these patterns. He finds, for example, the same gradients (as reservoirs of energy) and the same series of abrupt discontinuities in technological objects like steam engines, and in cultural objects like the paintings of Turner or the novels of Zola. Some Zola’s novels, in particular, are adept at linking the different types of disaster just mentioned (natural, engineering, social, psychological) thus constituting, in Serre’s own words, “a circulation of catastrophes”.[5] Thinking about catastrophes as critical events

[3] Ibid. p. 55.
[4] Ibid. p. 118-119.
[5] Michel Serres. It Was Before the (World) Exhibition. In The Bachelor Machines. (Rizzoli, New York, 1975), p. 69.

taking place over a range of scales—some striking with overwhelming force, others occurring at manageable intensities—suggests that some catastrophes may afford us not just risks but also opportunities. A life that is stable and routine, in which the consequences of our actions are always predictable, is not conducive to creativity. When artists find a style that is safe, a style that brings steady economic rewards, for example, they may become averse to innovation, since any novelty introduced into their lives is a risk, at the very least, the risk of failure. But for the same reason, such artists are likely to stagnate and lose their capacity to surprise. To avoid this fate many artists in history have deliberately lived their lives on the edge of manageable crises, in the vicinity of small catastrophes, although in some cases they may have underestimated the consequences of triggering critical events and paid dearly for it. This condition sometimes referred to as life at the edge of chaos, can also be explored mathematically to search for universal patterns.

The mathematics involved are very different from catastrophe theory. While the latter uses continuous mathematics (differential geometry, the calculus of variations) the edge of chaos is explored using discrete mathematics, the type made possible by digital computers. An important branch of this other type of math deploys populations of the simplest automata, machines that can carry out computations without using any memory, and investigates the effects of their interactions with each other. The interactions are determined by formal rules so it becomes possible to study the effect that the degree of rigidity of the rules has in the overall effect. In other words, the consequences of rules that are too rigid (like unchanging routines) or too loose (like a fully disordered life) can be explored. Sets of rules that are in between these two extremes, not too stable but not too unstable either, produce astonishing effects, the best example of which is the popular Game of Life. Although in principle the population of automata can consist of physical machines, in practice the automata are not hardware but software simulations. Each simulated automaton's position is fixed inside a polygonal cell; the automaton interacting only with neighbours whose cells shared vertices or edges. For this reason the field is called "cellular automata". In the Game of Life a deceptively simple set of rules governs interactions that change the state of each automaton depending on the state of its neighbours. Despite their simplicity, however, the rules lead to the emergence of an unexpectedly rich variety of collective patterns of states. Some of these patterns arise spontaneously, like the famous "glider", a collective pattern that moves diagonally across the automaton population. Others are designed using the basic ones as building blocks. It can be shown that using many natural and designed

patterns together an entire programmable computer can be built inside the space created by the Game of Life![6]

When scientists confronted this enormous potential, a potential that we may want to call "creative", they studied the only thing that could be responsible for it: the interaction rules. The space of possible rules contains many cases in which the patterns that result are boring and repetitive (rigid rules) or on the contrary, in which no pattern forms (loose rules). The rules of the Game of Life fall right in between the two extremes. The "sweet spot" seems to be located near the edge that separates the ordered from the disordered state (hence the expression "edge of chaos"). Or more exactly, it is located not right at the edge, a point that would be too precarious, but in its vicinity, displaced a bit towards the ordered side.[7] When the space of all possible rules was subjected to rigorous statistical analyses it became clear that the edge separating rigid routines from unregulated interaction had all the characteristics of a phase transition. In other words, the cellular automata that displayed the greatest creative potential were poised at the brink of catastrophe, but far enough from it not to trigger the critical event. The question then became whether this was a universal pattern and, in particular, whether physical phase transitions also possessed this creative potential. Some evidence exists that real processes poised at the edge between ordered and disordered states do in fact display spontaneous "computational" capacities. Indeed, biological evolution may have exploited the abilities that emerge in this special zone of intensity to endow its structures (membranes, cytoskeleton, the double helix itself) with flexibility and adaptability.[8] Although this extension of the findings of cellular automata to the material world is today highly speculative, it does point to important consequences: not only the rules by which we live our lives, but those that regulate our communities and organizations, cities and countries, may need to come from that special zone in the space of possible rules.

And if that turns out to be correct then catastrophes may not only be useful because they test our character and ability, but also because the neighbourhood of critical events may hold the secret to creativity.

[6] Christopher G. Langton. Life at the Edge of Chaos. In Artificial Life II. Edited by Christopher G. Langton, Charles Taylor, J. Doyne Farmer, Steen Rasmussen. (Redwood City: Addison-Wesley, 1992), p. 73.
[7] Ibid. p. 76.
[8] Ibid. p. 86.