You're getting warmer: Carnot knowledge (and power)

Let me offer one last relevant example of gradients and degradation—in part, to illustrate the key terms in this article's title; in part, to show their relevance to the core concerns of anthropology and the Anthropocene, at least at their origins; and, in part, to sketch the key features of one *countercosmology*. Such a nineteenth-century "causemology" not only succeeded in reframing space and time, intensity and causality, quality and relation, it also introduced four interrelated dimensions which are (soon to be) global cultural values as much as universal thermodynamic variables: energy, entropy, work, and temperature.

Temperature exhibits gradients: we may note its increase or decrease in passing from one point, or moment, to another. It is thus a quality (or dimension) that varies in quantity (or degree) depending on context. We grade temperature not only when we explicitly measure it (*the thermometer says it's 34 degrees Celsius*), but also when we implicitly compare the temperature of one place or period with another (*it's hot here [in comparison to there], it's hotter now [than it was then]*).

Whenever there is a spatial gradient in temperature, and an appropriate conduit or channel across the space, heat can flow from the hotter regions to the colder regions, a process which will eventually bring all points to the same temperature. That is, a temperature gradient causes a flow of heat which eventually cancels out the temperature gradation which caused it. This is an example of degradation—the loss of a gradient, resulting in the homogeneity of grade: *it's as warm here as it is there*.

Heat engines exploit such facts by taking in temperature gradients and turning out *work* (understood as the application of a force through a distance—say, lifting a mass, compressing a spring, accelerating a car, climbing a hill, or driving a wedge). Conversely, a refrigerator takes in work (or energy) and turns out a temperature gradient. And so just as gradients can be exploited to do work, work can be used to establish gradients. Indeed, we often use the energy released, or work performed, in leveling one gradient to establish another:[30] for example, using a heat engine to pump water into a cistern.

Crucially, in taking in heat from a higher temperature region and putting out heat into a lower temperature region, such an engine eventually makes both regions the same temperature—such that no more work can be done. While an ideal engine can be reversed, such that the same amount of work done *by* the engine can be done *on* the engine, and thereby return the two regions to their original temperatures, no heat engines are actually ideal. And so while energy is always conserved, as per the first law of thermodynamics, useful energy—and hence energy one can readily direct to desirable ends—is lost. This is another way to understand the second law

30. See note 16 of part 1 of this article for key caveats, extensions, and speculations. Schrödinger (1944), for example, argued that organisms are particularly good at capturing negative entropy (which he also referred to as "orderliness" and "free energy"). This is how they compensate for the entropy they create by living, and thereby maintain themselves at relatively low entropy levels. Indeed, he referred to this capacity to capture free energy, or relatively nondegraded energy, as the "organism's astonishing gift" (ibid.: 75). By capturing such fluxes, they keep themselves "alive," which is to say they keep themselves from coming to equilibrium with their environments, and thereby maintain a graded difference between themselves and their environments. In short, local order increases so far as global order decreases. And key gradients are not just those that vary across environments, but also those that separate organisms from their environments.

of thermodynamics, the idea that entropy is always increasing—or, equivalently, that energy is always degrading.[31]

Degradation is a key way to figure such loss, a loss that is inherently irreversible, a loss that grounds the inexorable directionality of time. What does it mean to live in such a world? Grace—to live, live well, and struggle so that all can live and live well, despite degradation. As if there was a point beyond life itself and its ceaseless cessation. Hope in the face of nope.

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Needless to say, the fact that these four dimensions (energy, work, entropy, temperature) are universal variables and global values does not mean they are the same everywhere, just locally salient everywhere (and globally significant). They must then be studied, in their local salience (and global significance), through all the techniques offered in parts 1 and 2 of this article—in particular, through "fieldwork" as it was theorized in part 1, as one key component of fieldwork (in its more traditional sense).

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The French engineer Sadi Carnot was one of the first to understand heat engines in regard to both their abstract potential and their historical particularity. As he saw it (Carnot [1824] 1897), such engines were radically open, insofar as they could replace all other sources of power (animals, rivers, wind, etc.). They were radically portable, insofar as they could be used to produce power at any time, in any place, on any scale (so long as one can produce a heat gradient there, which is as easy as burning coal). Like the other "mechanical arts," their key factors of production were iron and coal. But unlike the other mechanical arts, heat engines were recursively central to acquiring more iron and coal—through mining practices, in particular. Moreover, when employed in the form of steam engines on ships and trains, Carnot argued that such devices enabled communication, "the penetration of savage lands," the introduction of civilization, and the shortening of distance. (All the changes, incidentally, that McLuhan ([1964] 1994) would later argue, albeit with a relatively negative valence, that "media" helped to introduce.) Indeed, the steamship that Marlowe took upriver in *Heart of darkness* ([1899] 2007) was precisely such a vehicle. And Conrad's story, itself the foil for so much anthropological thought (at least since the 1960s), is filled with images of thermodynamic degradation amidst capitalist exploitation and colonial expansion: boilers, rusty rails, detonations, decaying machinery, puffs of smoke, and noise.

After making these claims, Carnot asked himself whether the motive power of heat was unbounded. And he compelled himself to think about this question in a completely general way ("independent of any particular agent"), and thus without regard to the specific details of the technology employed. He understood that you cannot get work out of heat, no matter how hot the source, unless there is something cold: a temperature differential is essential. He thought that, in addition to a

31. As should be clear from the examples offered in this article, not all gradients are good, and not all degradation is bad. That is, just as grading practices are relatively frame-dependent, so are evaluation practices (in regard to such grades).

heat source (say, a boiler) and sink, you need an "intermediary substance," something that changes size with temperature, such that it can push or pull, and thereby do work. And he argued that the motive power of such a device does not depend on the nature of this intermediate substance, but only on the temperature difference between the source (a region at a hotter temperature, *Th*) and the sink (a region at a colder temperature, *Tc*). He calculated the maximum efficiency of such an engine, equal to the work done (as output) divided by the heat absorbed (as input), showing it to be equal to (*Th* – *Tc*)/*Th*. In other words, so long as you have a temperature gradient, you have a source of power. In short, in offering his theory of thermodynamic mediation, Carnot described both the physical nature and the cultural ramifications of one of the most powerful and portable "agents" in world history.

Such a vision of temperature gradients, as generative of work and civilization, was the inverse imaginary of degradation and death, or the end of time, that was highlighted in 1854 by the German physicist Helmholz (quoted in Sethna 2006: 81; and see Thomson 1862), who suggested that all forms of energy would degrade into heat, and all temperatures would become equal, such that everything existing would "be condemned to a state of eternal rest." This idea was later foregrounded by H. G. Wells in *The time machine*, when he imagined what the state of the earth would be in the distant future, when all readily available gradients had been tapped:

> The sun, red and very large, halted motionless upon the horizon, a vast dome . . . glowing with a dull heat. . . . The earth had come to rest with one face to the sun, even as in our own time the moon faces the earth. . . . There were no breakers and no waves, for not a breadth of wind was stirring. Only a slight oily swell rose and fell like a gentle breathing, and showed that the eternal sea was still moving and living . . . the life of the old earth ebb[s] away . . . . ([1895] 2005: 66–67)

According to such nineteenth-century cosmologies, then, the heat engine was the original time machine—taking us all, ever faster, into this future.

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