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The Crisis of Communication in the Information Age: Revisiting C.P. Snow's Two Cultures in the Era of Fake News

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Abstract

The purpose of this paper is to revisit C.P. Snow's 'Two Cultures' lecture in light of the cultural dominance of information technology. The crisis of communication in the information age, whether in fake news, political polarisation or science denial, has come about because both scientific and literary cultures, in seeking a world without entropy, have inadvertently stumbled upon a world without meaning. In order to explain how this has happened, the paper first explores Snow's challenge: to describe the second law of thermodynamics. The paper then provides a description of entropy that is neutral with regard to thermodynamics and information, and not simply a measure of something more intuitive like disorder, uncertainty, mixed-up-ness, diffusion, complexity or emergence. Finally, the paper argues that Snow's suggestion that everyone should be able to describe the second law is timely right now because entropy is the bridge between information and reality, and the difference between science and science fiction.

Part 1, The Two Cultures and the Challenge of the Second Law

In his famous Rede lecture, in 1959, C.P. Snow expressed his concern and profound frustration at the condescension literary elites showed towards the sciences, and drew a stark contrast between the two cultures. The theme of the lecture was the need for scientific education and Snow's belief that the future would be based on scientific rather than literary culture. For 40 years, this seemed prescient. But now, as public confidence in science wanes and political discourse is inundated with populist sentimentality, it is worth revisiting Snow's comments, in particular his concern for the second law of thermodynamics:

> A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is about the scientific equivalent of Have you read a work of Shakespeare's? (Snow, 1959)

Like Hamlet's ‘to be, or not to be, that is the question’, the second law is simple: ‘in an isolated system, entropy may increase or stay the same.’ This may be why C.P. Snow felt like it could serve as a gateway to the scientific understanding of reality: it is a simple statement that applies to everything, everywhere, equally. And yet, there was a profound irony in Snow's choice of the second law. While there is a strong argument that it is the single most important principle in science, and that if you are going to know only one scientific theory, the second law should be it, it is also notoriously difficult to describe, more like describing Joyce's Finnegans Wake than a work of Shakespeare. Max Planck attempted to describe the law physically as follows:

> There does not exist a perpetual motion machine, of the second order, that is to say, a physical system, immersed in a heat bath, which, by cooling down (or, which is the same, by absorbing heat from the surrounding heat bath), can move a heavy body against a force, thus increasing its potential energy; or in terrestrial terms, a machine which, by cooling down, can lift a weight. (in Popper, 1957, p. 151)

Karl Popper was dissatisfied with Max Planck's description, and hoped that it could be replaced by something more compelling:

> I believe that most physicists will accordingly agree that the entropy law, in Planck's formulation, is simply falsified by the Brownian movement, as interpreted by Einstein... The present situation is logically highly unsatisfactory; for in many arguments within statistical mechanics (and also in information theory), use is made of the fact that certain events are impossible because otherwise the entropy law (in its phenomenological or Planckian form) would be violated. Clearly, all these arguments are circular. (Popper, 1957, p. 152)

Had Snow pursued his inquiry with more scientific rigour and asked a scientific audience the same question, he may have found agreement as to the importance of the second law, but no consensus as to how it should be described, and the situation has hardly improved. As the science writer Philip Ball explained in

2009, ‘I don't think I have ever succeeded in writing about thermodynamics without a surfeit of footnotes, for just about any simple statement in this connection needs clarification if it is not to be misleading, or downright wrong. (Ball, 2009, p. 111). And there is no higher level of understanding where it becomes clear. A review of quantum information in thermodynamics goes so far as to say that ‘if physical theories were people, thermodynamics would be the village witch. The other theories find her somewhat odd, somehow different in nature from the rest, yet everyone comes to her for advice, and no-one dares to contradict her. Einstein, for instance, called her “the only physical theory of universal content, which I am convinced, that within the framework of applicability of its basic concepts will never be overthrown”.’ (Goold et al., 2016)

Further investigation would also have unearthed the second law far afield from its scientific origins. In American jurisprudence, the second law appears in the Hand rule, which is approximately described as follows: the burden on a reasonable person to take precautions should not be greater than the loss that might occur times the probability of the accident that would cause the loss (Feldman and Kim, 2005). The rule is a simplified equilibrium equation, leaving out the logarithm, designed balance the cost of precaution against the uncertainty of possible accidents. Reasonable care, or non-negligence, is established when the cost of precautions spread evenly over phase space of foreseeable injuries is equal to the cost of the harm foreseeably arising from the injuries.

Snow should also have been aware that writers have been grappling with the second law in one form or another for as long as there has been writing. He need have looked no further than one of his English contemporaries, Virginia Woolf, whose final novel attempted to express meaning of being in terms of the details of living. In this passage, she might just as well have been grappling with the distribution of momentum of molecules in a bottle of gas:

> There must be another life, she thought, sinking back into her chair, exasperated. Not in dreams; but here and now, in this room, with living people. She felt as if she were standing on the edge of a precipice with her hair blown back; she was about to grasp something that just evaded her. There must be another life, here and now, she repeated. This is too short, too broken. We know nothing, even about ourselves. We're only just beginning, she thought, to understand, here and there. She hollowed her hands in her lap, just as Rose hollowed hers round her ears. She held

> her hands hollowed; she felt that she wanted to enclose the present moment; to make it stay; to fill it fuller and fuller, with the past, the present and the future, until it shone, whole, bright, deep with understanding. (Woolf, 1939)

Most writers succumb to magical thinking or well-defined tropes, but occasionally literature digs into the incomprehensible mess of what actually happens for no reason at all. In 1651, Jeremy Taylor wrote The Rule and Exercises of Holy Dying, in which he describes living in terms of the relationship between the froth and the bubbles on the surface of a pond under heavy rain:

> A man is a bubble, (said the Greek proverb), which Lucian represents with advantages and its proper circumstances, to this purpose; saying, that all the world is a storm, and men rise up in their several generations, like bubbles descending a Jove pluvio, from God and the dew of heaven, from a tear and drop of rain, from nature and Providence; and some of these instantly sink into the deluge of their first parent, and are hidden in a sheet of water, having had no other business in the world, but to be born, that they might be able to die: others float up and down two or three turns, and suddenly disappear and give their place to others: and they that live longest upon the face of the waters are in perpetual motion, restless and uneasy, and being crushed with a great drop of a cloud, sink into flatness and a froth; the change not being great, it being hardly possible it should be more a nothing than it was before. (Taylor, 1876)

Here, for the student of the second law, is entropy laid out both in terms of the slim probability of significant distinction and the inevitable convolution to the average. That the randomness of bubbles created by rain, most disappearing immediately, but some living on at the surface of the water for no obvious reason, not by any virtue or cause other than chance, and then dispersed into a foam, and finally indistinguishable from any other bubbles, having come to nothing in the end but a continuation of the average, should be seen as a fundamental condition of existence is the foundation of the second law.

Martin Heidegger, although generally uninterested in measurable physical phenomena, came to the same unsatisfactory conclusion that so troubled Popper: that the experience of being is fundamentally circular, so that the information about existence can never settle on a fixed model or construction, but must continually follow the convolutions of actual being:

> What is decisive is not to get out of the circle but to come into it the right way… In the circle is hidden a positive possibility of the most primordial

> kind of knowing. To be sure, we genuinely take hold of this possibility only when, in our interpretation, we have understood that our first, last and constant task is never to allow our fore-having, fore-sight and fore-conception to be presented to us by fancies and popular conceptions, but rather to make the scientific theme secure by working out these fore-structures in terms of the things themselves. (Heidegger, M., Being and Time, 1932, p. 195

Writing a book on being and time without mentioning Einstein, relativity or thermodynamics is like writing a book about airplanes without mentioning the Wright brothers, the airplane or jet engines, but it is worth noting that any rigorous inquiry into the nature of being leads to a similar place.

Snow, blithely unconcerned by the whirlpool that envelopes those who seriously consider the second law, envisioned a future governed by men of science, for whom the second law of thermodynamics was the bedrock of their worldview. It is hard to imagine a less accurate picture of the present. Yet he was right in thinking that an understanding of the second law would be crucial for governing in the future. The challenges facing this civilization, now, are fundamentally thermodynamic. Climate change, refugees and the flood of misinformation are all deeply connected to the entropy of the systems that Snow saw emerging from the great scientific advances of the early 20th century.

Since Snow's lecture in 1959, the concept of entropy has evolved from a physical quality with mathematical approximations to a mathematical puzzle with physical applications. This evolution is exemplified by recent books by Richard Dawkins (who pleads ignorance of thermodynamics rather than answer the question of whether life violates the second law in *Science in the Soul*), Stephen Pinker (who describes entropy reductively as ‘shit happens’ or a measure of disorder in *Enlightenment Now!*) and Arieh ben-Naim (who points out that the laws of thermodynamics do not do anything in *Four Laws that Do Not Drive the Universe)*. The philosophical trivialisation of thermodynamics has led scientists to discard what entropy means in favour of the many ways in which entropy may be calculated. Far and away the best modern book on entropy, Philip Ball's trilogy on *Shapes in Nature*, mentions entropy only a handful of times. Entropy is a relic from the time before computer models and high-energy particle accelerators. In a computer simulation, as in quantum mechanics, all interactions are equally reversible and the second law is just an inconvenient artefact of ‘reality’.

As Jeffrey Wicken (1987) observed, the introduction of an entropy of information has not served to elevate entropy to a universal quality so much as further obscure its physical significance. Wicken proposes replacing ‘entropy’ with ‘complexity’ in the context of information and communication, because, as he puts it, ‘the basis for assigning a thermodynamic system an entropy comes from the irreducibility of its uncertainty concerning matter-energy distribution’ (Wicken, 1987).

Wicken argues against the use of the term ‘entropy’ in information systems because, at least superficially, the construction of a message involves a choice of microstates, not an uncertainty of microstates:

> The starting point for the Shannon entropy is an alphabet of symbols which have the capacity to convey information because they can be transmitted in alternative sequences. The entire ensemble of possible sequences can be abstractly assigned an ‘entropy’, which measures the uncertainty connected with knowing a priori the sequence of elements in any given message. Shannon initially suggests (Shannon and Weaver 1949, p. 49) that information is carved from that entropic space. This much can at least be borne in a spirit of suspended judgment. But he slips immediately (p. 50) to assigning entropies to the symbols and messages themselves. Here he permanently parts company with statistical entropy. (Wicken, 1987, p. 180-181)

Wicken is correct that entropy only arises where the macrostate is not well-defined in terms of its microstates, and that this is not the case for a words you choose to write with well-defined letters. However, words in the abstract are not well defined, but carved from the entropic space of all possible identifiable marks. To use Shannon's communication heuristic: the word ‘bubble’ has nothing to do with having 3 b's, and one u, l, and e in any particular order. As a word, it has everything to do with being distinguishable from the words ‘bustle’, ‘buckle’, other similar words, and every other word. This distinguishability depends on the distinguishability of its letters and their distribution, so that its Shannon entropy, i.e., its communicability, depends on the rarity of its letter pattern, which can be represented by the letter pattern (1,b), (2,u), (3,b), (4,b), (5,l), (6,e). It's entropy does not come from some uncertainty about whether I will spell bubble that way, but rather from the receiver's uncertainty about what I was trying to spell when she receives the message ‘bubble’; and from her ability to distinguish it from the other possibilities in the context. Shannon's heuristic mischaracterises the nature of language by taking the receiver's capacity to comprehend for granted, which is why his alphabetical description of information entropy loses touch with thermodynamic entropy. But Wicken is too quick to dismiss the entropy of communication based on this oversight. The language here is serving three functions, as vehicle for communication, object of communication and heuristic for explaining the object. It's easy to get confused.

Indeed, the greatest challenge in trying to communicate about entropy is the fact that you cannot avoid confusion and convolution. Whether in information theory or thermodynamics, confusion and convolution are precisely what you are trying to discuss. Entropy provides a mathematical representation of a system where the whole cannot be well-defined in terms of its individual parts. Creating a well-defined model of a system and then assigning it an entropy based on the abstract relationship that you have created between its parts may be heuristically helpful, but it misses the point of entropy. In a paper on the variations in the mathematical description of entropy, Charlotte Werndl and Roman Frigg also engage in the fabrication of a system to illustrate how Boltzmann and Gibbs can be seen to disagree under special conditions. However, they seem to conflate the information they choose to describe the system with the physical properties of the system:

> Consider the baker's gas (Section 3) with an even number of particles with one macro-variable V indicating whether there are more particles on the left side of the container than on the right side: V assumes value 1 if there are more particles on the left and it assumes value 0 if there are more particles on the right. The corresponding macro states are M1and M0. Both macro-regions have the same measure, namely 1/2. The dynamics is ergodic and therefore the system spends half of the time in M0 and half of the time in M1. For this reason the system has no Boltzmannian equilibrium (neither of the α-ε nor of the γ-ε kind). However, there exists a Gibbs equilibrium: the uniform measure μB is the stationary distribution of maximum entropy. (Werndl and Frigg, 2017)

What is clear, even in modern discussions of entropy, is that it is necessary to fictionalise the system in order to say anything meaningful about its entropy. The hypothetical entropy in Werndl and Frigg's system, with two arbitrarily defined macrostates (more particles on one side than the other), suffers from the same defect that Wicken attributes to Shannon's alphabetical choice. A choice does not have an entropy. Even if we grant the arbitrary definition of the system, there is no way to measure the predominance of molecules in one side or the other so the states can only be defined as in physical superposition. This is not a quantum mechanical effect, but an effect of a lack of information. Information about a real system cannot be hypothecated, it must be earned by measurement, with all of the associated costs. Arieh ben-Naim's critique of the Gibbs Paradox of the entropy of mixing resolves the issue slightly differently, but the point is the same (Ben-Naim, 2007). If you have no information about a system, its states are in superposition, and from your perspective, its entropy is maximised, whether it is actually mixed or not, actually balanced or not. There is no absolute perspective from which to observe its real entropy.

There is a deeper problem in the relationship between information and thermodynamics that springs from the abstractness of the human imagination. Maxwell's demon arose from the idea that the imagination exists in isolation from physical processes, that information is not fundamentally physical, but abstract, etherial and metaphysical. Even for materialists, this idea is hard to escape. The imagination soars without wings, how could it have an entropy? And yet, there can be no question but that the experience of imaginary events, the information space in which they can be observed and evaluated, cannot exist without information derived from physical sense perceptions. Without going into the question of how consciousness arises (if it is an emergent quality, then there is no further investigation), we need to understand why consciousness sees its imagined information as separate from the physical perceptions from which the information is derived. We need to understand how the imagination is effortlessly seduced into believing that its information predates and controls reality.

The notion of a deterministic universe has survived without theoretical or empirical foundations from Genesis to Einstein. In the beginning, was the word. Karl Popper tried, unsuccessfully, to dispel this seduction in his great argument against physical determinism:

> I believe that Peirce was right in holding that all clocks are clouds, to some considerable degree - even the most precise of clocks. This, I think, is a most important inversion of the mistaken determinist view that all clouds are clocks. I further believe that Peirce was right in holding that this view was compatible with the classical physics of Newton. I believe that this view is even more clearly compatible with Einstein's (special) relativity theory, and it is still more clearly compatible with the new quantum theory. In other words, I am an indeterminist-like Peirce,

> Compton, and most other contemporary physicists; and I believe, with most of them, that Einstein was mistaken in trying to hold fast to determinism. (I may perhaps say that I discussed this matter with him, and that I did not find him adamant.) (Popper, 1965)

Here, Popper describes two competing world views in science: one where clouds are made up of minute clocks (the clockwork universe), and another where clocks are made up of minute clouds (the probabilistic worldview). His argument is forceful, but may have missed the mark by failing to address the worldview based on waves which continues through to modern string theory. The underlying wave theory might explain why people could, despite statistical mechanics and all other evidence to the contrary, think of clouds as made up of clocks. All clocks are based on the wave equation of a harmonic oscillator. Not only that, but if particles are construed as waves, then every cloud appears to be made of something clock-like. The problem with this intuition is that every particle is also a particle in space, and therefore a cloud, and while every wave is analytically perfect in the abstract, its actual location in space is not, which is why the cloud comes first, followed by waves only when a discontinuity appears.

Indeed, the notion that the universe is a clockwork may arise from the fact that every wave is perfect. Whether a particle wave, ocean wave, seismic wave or gravitational wave, there is only one wave equation (Fleisch and Kinnaman, 2015). The physical perfection of waves means that any object that makes waves can receive similar wave and that any physical system can, through some harmonic progression, communicate with any other physical system. It also means that all communication methods are arbitrary and interchangeable. Combined with Shannon's universal theory of communication (Shanon, 1948) and Turing's universal computing, the universal physical wave form creates the illusion that the universe is a clockwork, an information system. But waves must exist in something else, something continuous, fluid and not wavelike; and communication, while universal, depends on discontinuities in something continuous and uninformative. Like energy, every bit of information is a discontinuity in a larger, undefined field of potential. That larger field is neither energy nor information nor wave-like. It has no analytical definition, but it has the global quality of entropy.

Although the mathematical representations are separate, waves are, in fact, linked back to thermodynamics by the fact that every wave is generated by an increase in entropy that exceeds the threshold for local random motion, i.e., the additional energy cannot be absorbed into the local equilibrium as heat. This increase in entropy radiates through the medium in wave form until it either attenuates into the entropy of the medium or reaches a damper that can break the wave and absorb the energy, as sand on a beach. Every wave, and by extension every bit of information, is associated with some amount of energy. What makes this connection so unintuitive is that the amount of energy is arbitrary. One wave, or one bit of information, can contain any amount of information as long as it is greater than zero (and less than the Schwartzschild limit). One could, theoretically, use all of the energy produced in the USA to produce one bitcoin.

Another way of looking at a wave is as the normal distribution of potential and kinetic energy, separated by half a period in space and time. When potential is maximum, kinetic is minimum and vice versa. Near equilibrium, kinetic and potential energy are indistinguishable and superimposed on one another, but when an energy gradient exceeds the limit of the equilibrium state, kinetic and potential are separated and they follow one another away from the source until eventually they recombine, either by breaking against an object or dispersing into the medium. The wave carries energy and information because the kinetic and potential energies are separate, not because the thermodynamic entropy of the system is changed. The distribution of both retain random distributions, and those distributions show up in the wave's shape. A wave looks like a bell curve because a wave is a bell curve. The shape of a wave is no less random than the distribution of momenta in a body at equilibrium, the difference is simply that the kinetic and potential parts of the distribution are separate in a moving wave.

Ultimately, Popper's argument is against determinism, but his argument illustrates the temptation to ignore the entropy of the field and focus on the information content of the waves moving through it, losing sight of the arbitrary amount of energy that is contained in the information. It is difficult to explain away the intuition of universal determinism without fully explaining the perfection of the waves we perceive. This perfection is not an illusion, and it is a constant reinforcement for the intuition that the universe has some underlying and determinist perfection.

At this point, you may reasonably ask why I am interested in two philosophical lectures from the 1950s: surely, science and philosophy have evolved since then. Unfortunately, what has evolved is not so much a consensus as a detente. Each field maintains its own definition of entropy and none attempts to produce the phenomenological underpinnings that Popper demanded. The second law, far from Snow's gateway to scientific understanding, has been reduced to a disclaimer or necessary evil, like the ingredients list on a box of cereal.

Part 2: A Phenomenology of Entropy

Entropy describes the relationship between the ensemble and its parts. Because the parts of an ensemble generally have no similarity with or logical connection to the body they make up, entropy is almost incomprehensible. In thermodynamics, entropy is the position and momentum of all of the particles in a given volume of space, but the concept is equally applicable to the relationship between sounds and statements, between animals and their species, or between people and committees. Boltzmann realised that Darwin and Clausius were working on the same problem and formulated the limit of what can be known about it in terms of the probability that a given set of parts will make a whole with particular qualities.

If you could know the complete entropy of the mass/energy in a given region, you would know the chemical composition of everything in it; you would know how much information was mapped in its structure and how much information it could transmit, as well its energy content and potential. This true entropy is immeasurable. This immeasurability is most obvious at the subatomic scale where Heisenberg uncertainty is prohibitive, but the appearance of entropy tends to be scale invariant: the ratio of what you can measure to what is really there is pretty much the same no matter how big or how small your subject matter. Self-organising phenomena, things that organise themselves by virtue of their own entropy, will tend to have the same pattern at all scales. This scale-invariance makes entropy equally applicable to storms and teacups, whirlpools and galaxies, governments and molecules Self-organisation illustrates how entropy is not a measure of disorder, but is as likely to cause order as disorder, and is generally indifferent to both. As Wicken explains, 'the casual usage of such terms as "disorder" and "disorganization" to provide pictorial clarity to the concept of entropy has served primarily to obscure its meaning' (Wicken, 1987, p. 183).

A more ecumenical way of looking at thermodynamics is to say that energy is the communication of force or radiation from one thing to another while entropy is the relationship established by that communication. This translation between energy and entropy holds for all scales, whether you are talking about particles, billiard balls or human beings in a society. If you shoot a cue ball into a group of balls, you can see how its force is translated into a set of relationships after it strikes the balls, and that each ensuing collision communicates force from one ball to the other, while altering all of the relationships (relative momentum and position) between the balls. Energy is the obsession of animals; for a plant, energy just isn't all that interesting; the flux of entropy is far more important than energy available for ‘work’, so molecules with high energy potentials like O2 (and even sugars) can be discarded as waste.

This formulation also illustrates why Shannon's information entropy looks the same as Boltzmann's thermodynamic entropy. Energy, like information, only exists in transmission. Both equations define how much stuff, either information or energy, can be communicated by the configuration or relationships of a given physical system. This is more obvious for information, but remember that there is no way to know how much energy is ‘contained’ in an object unless it transmits some of its energy and information to another object. Two systems that are both in equilibrium with a third system are in equilibrium with each other. This is also true of resonance, where two systems that are both in tune with a third system are in tune with each other because every wave is perfect. Communication only occurs where information passes in waves between resonators.

The problem with modern mathematical models of information and thermodynamics is that they ignore the form of the body in space, which is essential for communication to have any relevance or meaning. This is like leaving the caffeine out of coffee, the sex out of romance, or the alcohol out of beer. It gives you a notion about the thing, but it misses the point. To say that the entropy of a system is the sum of its possible micro-states multiplied by the logarithm of its total number of micro-states, consistent with its macroscopic thermodynamic properties, is a bit like the old joke about the balloonist who is lost in a fog: when, in a clearing, he sees a person on the ground, the balloonist shouts down ‘where am I?’, to which the person replies ‘you're in a balloon.’

Part 3, The Crisis of Communication:

> We, like diminished kings or rigidly insecure presidents, are reduced to being overwhelmed by info and interpretation, or else paralyzed by cynicism and anomie, or else – worse – seduced by some particular set of dogmatic talking-points, whether these be PC or NRA, rationalist or evangelical, 'Cut and Run' or 'no Blood for Oil.' The whole thing is (once again) way too complicated to do justice to in a guest intro, but one last, unabashed bias/preference in *BAE '07* (Best American Essays, 2007) is for pieces that undercut reflexive dogma, that essay to do their own Decidering in good faith and full measure, that eschew the deletion of all parts of reality that do not fit the narrow aperture of, say for instance, those cretinous fundamentalists who insist that creationism should be taught alongside science in public schools, or those sneering materialists who insist that all serious Christians are just as cretinous as the fundamentalists. Part of our emergency is that it's so tempting to do this sort of thing now, to retreat to narrow arrogance, pre-formed positions, rigid filters, the 'moral clarity' of the immature. The alternative is dealing with massive, high-entropy amounts of info and ambiguity and conflict and flux; it's continually discovering new vistas of personal ignorance and delusion. In sum, to really try to be informed and literate today is to feel stupid nearly all the time and to need help. (Wallace, D. F. 2007)

David Foster Wallace has an intuitive sense that high-entropy means noise, and that a flood of information makes people uncomfortable to the point where ignorance is preferable to any attempt at informed decision making. Bigoted, isolationist political discourse is particularly appealing in this context, but this is not new. This is not the first time a bloviating, chauvinist megalomaniac took power in a major industrialised nation, so it is impossible to place the blame at the feet of digital technology or total noise. Still, digital technology serves no other purpose other than to alleviate ignorance, so we may start with the question: given the immense public and private investment in digital technology, why has it failed so spectacularly at the one thing it was supposed to accomplish?

One answer lies in David Foster Wallace's curious use of the word entropy. It is true that the flood of information distributed through modern digital technology contains a massive amount of information, but is it high-entropy? When was the last time you saw a fuzzy tv screen or heard static on an audio feed? Not only is the information incredibly clean, but the content has been edited, categorised and scoured of anything that you might find hard to understand. The information has been curated to ensure effortless comprehensibility. If it is surprising, the surprise is calculated to draw your attention back to the expected resolution. The information system has been engineered to eliminate errors in transmission, and the content has been produced to ensure unconscious acceptability. The entropy of the information we consume is spectacularly low.

High entropy may be intuitively synonymous with noise, and, in thermodynamic terms, it is associated with indistinguishability. But a low-entropy signal like a sine wave cannot carry information, so it is also noise, equally useless for communication. The stream of information Wallace is talking about, the internet and cable television, has extremely low entropy. It may be equal in daily volume to an unabridged Oxford English Dictionary, but it is too repetitive and predictable to be informative, like the definition of the word "word" repeating over and over.

Low entropy noise is hard to recognise as noise, and it is much harder to filter out than high entropy noise. Rain on a tin roof is high-entropy noise – random, unpredictable and pleasant. Low entropy noise is more like a steadily dripping tap – ordered, predictable and maddening. In Shannon's terms, the steady drip is totally compressible in that you could compress an hour of steady drips into one drip on repeat with no loss of information. Its informational entropy is low. However, while your mind can effortlessly ignore the rain, that steady drip keeps coming back, drilling into your head. The same is true of the modern information overload. It is possible that we have no more cultural (human) information now than we had in 1932; we just have an immeasurable number of duplicates, replicas and semblances. You could, for example, compress a week's worth of news, drama and sport into an hour without missing anything. However, because the entropy of the information is low, you can't block it out of your daily routine. Not only are the duplicates uninformative, they make it harder to find anything worth looking at, new or old.

Wallace was not talking about Shannon entropy here. He was talking about the high uncertainty of the *meaning* of the information, which is something Shannon never addressed. You can see why this leap is tempting, but the idea of judging whether the *meaning* of a statement is ordered or disordered, compressible or uncompressible, is many times more complex than distinguishing between an ordered or disordered message, which is itself an uncertain task outside of the most formal settings.

Meaning is not a sign of low entropy. Meaning is a transformation. Like the difference between the reversible entropy of a Carnot cycle and the actual entropy of a heat engine, meaning is that part of a communication that is irreversible. That's the part that gets lost in calculation. The meaningful part of entropy is not the overall ‘mixed-upness’ or disorder of the system; it is the irreversible transformation of the system. Entropy means inner transformation, and whether it is due to an irreversible disorder or an irreversible order is irrelevant. The point is that you can't get back to the starting point without adding something: energy, mass, charge, space, etc. Every interaction causes a transformation, but at the moment of the interaction there is no way to distinguish between the part of the transformation that is reversible and the part that it irreversible. You have to wait and see what doesn't spontaneously reverse itself. It all looks the same until the Carnot cycle doesn't quite come back to its starting position. That is why the guts of entropy are inaccessible. Entropy has a form and a moment, but the part that is meaningful is indistinguishable from the part that is meaningless.

This irreversible transformation is fundamental to the meaning of information as well. All information causes a transformation. Meaningful information causes a transformation that is irreversible. Like physical entropy, meaning also has a form and a moment, but no measurable dimensions to distinguish it from meaningless information. Meaning is the information you can't un-know, for good or ill and for reasons that are inexplicable. Remember the noises of drips and rain? They may be annoying or soothing, but once they stop they are gone. The transformation is reversible. The songs that get stuck in your head are different. One thing about meaningful information is that it's entropy (Shannon entropy) can't be too low or too high. You can't get a steady beat stuck in your head any more than you can get a whole symphony stuck in your head, but think of the themes from Mozart's *Requiem*, Dvorak's *Cello Concerto*, or Beethoven's 5th and 9th symphonies, those simple tunes that haunt the whole ensemble of sound and never leave you. The entropy of songs that get stuck in your head is a little too low to engage your intellect, so they tend to be annoying after a while, but they're just right for some part of your brain that predates your sense of control, maybe from way back before the dinosaurs. The meaning of a message is the part that changes how you will perceive the world, not the sum total or average value of its statements.

The crisis of communication, which is not unique to the information age, but is particularly acute now, arises from the fact that people prefer fake news to real news, so fake news spreads faster, farther and deeper than anything approaching truth. Investigative journalism exists because you can get better details in the field than you can make up in your head. The public may not want the same fake news over and over again, but they do want real facts that confirm their predictive assumptions over and over again. Alternative facts can be substituted where real ones fail. A made-up story is more likely to fit effortlessly into our information space than a ‘true’ story because reality has a fundamentally different entropy from imagination. Great stories allow effortless thinking by slipping seamlessly into common knowledge. They may pick up ‘facts’ from real events, but their explanations and transformations between events are made to fit into information space in a way that does not resemble real entropy. This, in the end, is the point. Without a cultural understanding of entropy from both the informational and thermodynamic perspective, it is difficult to describe the difference between fictions that illuminate inaccessible qualities of real phenomena and lies that obfuscate real phenomena to promote irrational prejudices.

It is, after all, impossible to describe the entropy of real events without fiction. This means that it is necessary to distinguish between a fiction that reaches for truth and simple lies. In his story/essay ‘How to Tell a True War Story’, Tim O'Brien illustrates the circularity in the relationship between information and reality, and how hard it is to find a satisfying end to the cycle:

> In any war story, but especially a true one, it’s difficult to separate what happened from what seemed to happen. What seems to happen becomes its own happening and has to be told that way. The angles of vision are skewed. When a booby trap explodes, you close your eyes and duck and float outside yourself. When a guy dies, like Lemon, you look away and then look back for a moment and then look away again. The pictures get jumbled; you tend to miss a lot. And then afterward, when you go to tell about it, there is always that surreal seemingness, which makes the story seem untrue, but which in fact represents the hard and exact truth as it seemed.
>
> In many cases a true war story cannot be believed. If you believe it, be skeptical. It’s a question of credibility. Often the crazy stuff is true and the normal stuff isn’t because the normal stuff is necessary to make you believe the truly incredible craziness.
>
> In other cases you can’t even tell a true war story. Sometimes it’s just beyond telling.
>
> I heard this one, for example, from Mitchell Sanders. It was near dusk and we were sitting at my foxhole along a wide, muddy river north of Quang

Ngai. I remember how peaceful the twilight was. A deep pinkish red spilled out on the river, which moved without sound, and in the morning we would cross the river and march west into the mountains. The occasion was right for a good story.

"God's truth," Mitchell Sanders said. "A six-man patrol goes up into the mountains on a basic listening-post operation. The idea's to spend a week up there, just lie low and listen for enemy movement. They've got a radio along, so if they hear anything suspicious—anything— they're supposed to call in artillery or gunships, whatever it takes. Otherwise they keep strict field discipline. Absolute silence. They just listen….

"So, after a couple days the guys start hearing this real soft, kind of wacked-out music. Weird echoes and stuff. Like a radio or something, but its not a radio, it's this strange gook music that comes right out of the rocks. Faraway, sort of, but right up close, too. They try to ignore it. But it's a listening post, right? So they listen. And every night they keep hearing this crazyass gook concert. All kinds of chimes and xylophones. I mean, this is wilderness—no way, it can't be real—but there it is, like the mountains are tuned in to Radio Fucking Hanoi....

"These six guys… they're pretty fried out by now, and one night they start hearing voices. Like at a cocktail party. That's what it sounds like, this big swank gook cocktail party somewhere out there in the fog. Music and chitchat and stuff. It's crazy, I know, but they hear the champagne corks. They hear the actual martini glasses. Real hoity-toity, all very civilized, except this isn't civilization. This is Nam….

"All these different voices. Not human voices, though. Because it's the mountains. Follow me? The rock—it's *talking*. And the fog, too, and the grass and the goddamn mongooses. Everything talks. The trees talk politics, the monkeys talk religion. The whole country. Vietnam, the place talks….

"The guys can't cope. They lose it. They get on the radio and report enemy movement—a whole army, they say—and they order up the firepower. They get arty and gunships. They call in air strikes. And I'll tell you, they fuckin' crash that cocktail party. All night long, they just smoke those mountains. They make jungle juice. They blow away trees and glee clubs and whatever else there is to blow away. Scorch time. They walk napalm up and down the ridges. They bring in the Cobras and F-4s, they use Willie Peter and HE and incendiaries. It's all fire. They make those mountains burn.

"Around dawn things finally get quiet. Like you never even heard quiet before. One of those real thick, real misty days—just clouds and fog, they're off in this special zone—and the mountains are absolutely dead-flat silent. Like *Brigadoon*—pure vapor, you know? Everything's all sucked up inside the fog. Not a single sound, except they still *hear* it.

> "So they pack up and start humping. They head down the mountain, back to base camp, and when they get there they don't say diddly. They don't talk. Not a word, like they're deaf and dumb. Later on this fat bird colonel comes up and asks what the hell happened out there. What'd they hear? Why all the ordnance? The man's ragged out, he gets down tight on their case. I mean, they spent six trillion dollars on firepower, and this fatass colonel wants answers, he wants to know what the fuckin' story is.
> "But the guys don't say zip. They just look at him for a while, sort of funny like, sort of amazed, and the whole war is right there in that stare. It says everything you can't ever say. It says, man, you got wax in your ears. It says, poor bastard, you'll never know—wrong frequency—you don't even want to hear this. Then they salute the fucker and walk away, because certain stories you don't ever tell."
> You can tell a true war story by the way it never seems to end. Not then, not ever. Not when Mitchell Sanders stood up and moved off into the dark.
> It all happened….
> In the end, of course, a true war story is never about war. It's about the special way that dawn spreads out on a river when you know you must cross the river and march into the mountains and do things you are afraid to do. It's about love and memory. It's about sorrow. It's about sisters who never write back and people who never listen. (O'Brien, 1990, pp. 67-72, 81)

And in this way, the second law is not about thermodynamics, it is about space and time; it is about justice. It is about the peculiar shape of things that you can't control. It is about everything else that matters, and why it matters. In his Rede lecture, Snow was not declaring the superiority of scientific understanding over literary understanding. He was trying to explain a crisis of communication that he perceived to have dire political consequences. His naive intuition was that the future would belong to the culture that could describe the second law of thermodynamics, at the very least, and his fear was that this might be the Soviet culture and not the British one. In the end, Soviet scientism failed, at least in part because it was devoid of humanism, while western scientism produced the digital revolution, the internet, and finally Brexit and Donald Trump. The crisis of communication that Snow felt when passing between literary and scientific circles seems to have expanded to the whole culture, where fake news and real news are increasingly indistinguishable and political communication is in disarray. If great scientific minds like Schrodinger, Popper and Dawkins were all befuddled by thermodynamics, what hope is there for the rest of us? I would argue that we have no hope, but we have an equal right and obligation to explore thermodynamics and get it wrong, over and over, until we approach the limit of comprehension. It may difficult and unpleasant, but thermodynamics holds the key to understanding the relationship between the information we use to communicate and the physical world on which we depend for our survival, both cultural and physical. While I believe that Snow's Two Cultures lecture was presumptuous and dismissive with respect to both literature and the science of thermodynamics, I also agree with his assertion that entropy, like literature and mathematics, must be one of the pillars of education. In the same way that electricity got its name from amber because that was the first material known to have electrical properties, the second law is associated with thermodynamics because heat was the first phenomenon related to entropy. In this future, entropy must be understood as the essential complement to all logical processes, and that nothing can be governed without a deep understanding of the second law.

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