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Article

Thermodynamics ≠ Information Theory: Science's Greatest Sokal Affair

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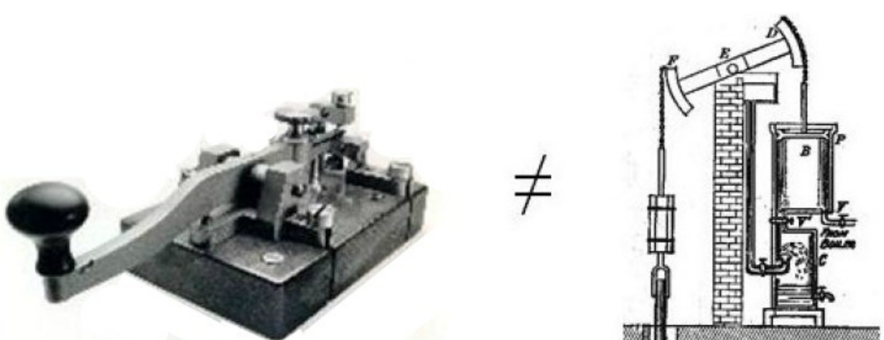
Abstract

This short article is a long-overdue, seven decades—1940 to present—delayed, inter-science departmental memorandum—though not the first—that INFORMATION THEORY IS NOT THERMODYNAMICS and *thermodynamics is not information theory*. We repeat again: *information theory*—the mathematical study of the transmission of information in binary format and or the study of the probabilistic decoding of keys and cyphers in cryptograms—is *not* thermodynamics! This point cannot be overemphasized enough, nor restated in various ways enough. Information theory is not statistical mechanics—information theory is not statistical thermodynamics—information theory is not a branch of physics. Claude Shannon is not a thermodynamicist. Heat is not a binary digit. A telegraph operator is not a Maxwell's demon. The statistical theory of radiography and electrical signal transmission is NOT gas theory. The equations used in communication theory have **absolutely** ~~**nothing** to do~~ with the equations used in thermodynamics, statistical mechanics, or statistical thermodynamics. The logarithm is not a panacea. Boltzmann was not thinking of entropy in 1894 as 'missing information'. Concisely, the truncated abstract of this article is: thermodynamics ≠ information theory. In pictorial form, the abstract of this article is:



Telegraph Machine ≠ Heat Engine

Neumann-Shannon anecdote

> "**Neumann's proposal** to call Shannon's function defining *information* by the name 'entropy' **opened a Pandora's box** of intellectual confusion."
>
> — Antoine Danchin (2001), French geneticist[1]

The roots of this article trace to what known as the Neumann-Shannon anecdote, a famous, or rather *infamous*, depending on point of view, discussion between American mathematician and communications engineer Claude Shannon, shown below left, and Hungarian-born American mathematician and chemical engineer John Neumann, shown below right, which occurred in the period between fall 1940 to spring 1941, during Shannon's postdoctoral year at the Institute for Advanced Study, Princeton, New Jersey, during which time Shannon was wavering on whether or not to call his new logarithm formulation, shown below, of communications in signal transmissions by the name of either <u>information</u>—as in binary coded *information* sent via a telegraph transmission—or <u>uncertainty</u>—of the Heisenberg *uncertainty* type, i.e. of 'uncertainty' in the mind of someone about to receive a message?[2] Several alternately worded versions of the anecdote exist.[3] The following is a popular version (with image) from the 2010 book *Biomedical Informatics* by German computer processing scientist and cognitive researcher Andreas Holzinger:[4]

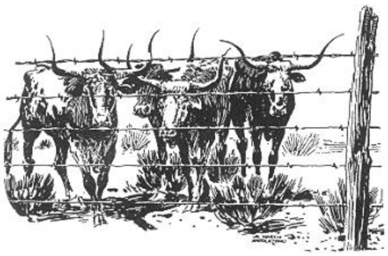
$$H = \sum_{i=1}^{n} p_i \log_2 p_i$$

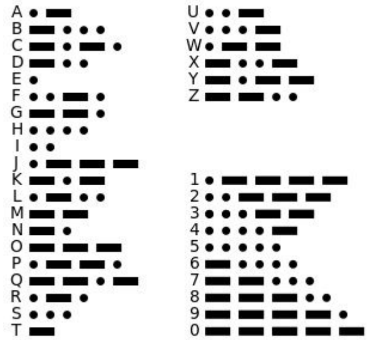
Claude Shannon

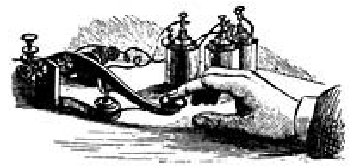
John Neumann

> *My greatest concern was what to call it. I thought of calling it "information", but the word was overly used, so I decided to call it "uncertainty". When I discussed it with John von Neumann, he had a better idea. Von Neumann told me, "You should call it entropy, for two reasons. In the first place your uncertainty function has been used in statistical mechanics under that name, so it already has a name. In the second place, and more important, nobody knows what entropy really is, so in a debate you will always have the advantage."*

Shannon, prior to this famously-repeated 1940 conversation, had developed a long-standing passion for signal transmission. The earliest mention of this was when as a boy in *circa* 1926 he used a telegraph machine to send Morris code messages to his neighborhood friend a ½-mile away through the barbed wire that ran along the road, as summarized below:[5]







American Claude Shannon (1916-2001), as a boy, *circa* 1926, in Gaylord, Michigan, hooked up a telegraph machine to the barbed wire fence (left) that ran along his country road so that he could communicate with his neighborhood friend a ½-mile away, using Morse code (center): a 1836 communication system developed by American Samuel Morse, according to which the telegraph system (right) could be used to send coded pulses—dots (short hold) or dashes (long hold)—of electric current along a wire which controlled an electromagnet that was located at the receiving end of the telegraph system.[5]

The barbed wire photo shown, to note, is of a Texas area farm rather than a Michigan area farm—put the point is still the same: tapping out 'hey, what are you doing' on a single button telegraph board—or for that matter typing your daily email on a modern 61-button Dvorak Simplified Keyboard, and the various coding formulas underlying the *transmission* of these communications are NOT measures of Boltzmann entropy.

To clarify, however, before proceeding further, there is a real physical-chemical perspective in which entropy—of the real thermodynamic variety—seems to be a quantitative factor in the sending of messages between people, such as via in person verbal speech, post, telegraph, email, text messaging, Skype, etc., but this is an advanced subject of *human chemical thermodynamics*, which holds firstly that each person is a surface-attached reactive *molecule*, a twenty-six-element human molecule to be specific, and secondly that the binding and or debinding of molecules—people—is completely 'determined', in the words of American-born Canadian *bio*physical[N4] chemist Julie Forman-Kay, by 'the free energy change of the interaction, composed of both enthalpic and entropic terms'.[6] Hence, any interaction between two people, such as typing out 'LOL' in text message, is a factor—composed of both enthalpic and or entropic terms—involved in the reactionary chemical binding or debonding of two people.[196] To clarify further, in this sense, we are not referring to the 'physical irregularities and functional degradation, an unreliability resulting from the physical effect of the second law in the real world of signal transmissions', in the 2011 words of American anthropological neuroscientist Terrence Deacon, that REAL ${dQ}/_{T}$ entropy differs from SHANNON bit entropy, but rather the way in which entropy plays a role in spontaneous direction of chemical reactions, atomic or human.[220] This, however, is a subject beyond the scope of the present article.[7]

The objective herein is to show that the so-called Shannon entropy (information theoretic entropy)—or specifically the one time Shannon uses the term 'entropy' in his 1945 article 'A Mathematical theory of Cryptography' and 152 times Shannon uses the term 'entropy' in his 1948 article 'A Mathematical Theory of Communication', namely: conditional entropy, entropy of two possibilities, entropy of a source, entropy of a joint event, the **uncertainty (or entropy)** of a joint event—here we see Shannon vacillating on terminology (an inconsistency point we will dig into in the following article)—entropy of a source per symbol of text, entropy per second, entropy per symbol of blocks, relative entropy, entropy of the approximations to English, entropy per unit time, entropy of symbols on a channel, entropy of the channel input per second, true entropy, actual entropy, maximum possible entropy, zero entropy, maximum entropy source, joint entropy of input and output, the entropy of the output when the input is known and conversely, entropy as a measure of uncertainty, input entropy to a channel, entropy of a continuous distribution, entropy of discrete set of probabilities, entropy of an averaged distribution, entropy of a one-dimensional Gaussian distribution, the entropy as a measure in a an absolute way of the randomness of a chance variable, new entropy, old entropy, entropy of an ensemble of functions, entropy of an ensemble per degree of freedom, maximum possible entropy of white noise, entropy of a continuous stochastic process, entropy power, maximum entropy for a given power, entropy power of a noise, entropy loss in linear filters, change of entropy with a change of coordinates, entropy power factor, entropy power gain (in decibels), final power entropy, initial power entropy, output power entropy, entropy power loss, entropy of a sum of two ensembles, entropy power of a distribution, definite entropy of noise, entropy of a received signal less the entropy of noise, maximum entropy of a received signal, greatest possible entropy for a power, entropy (per second) of a received ensemble, noise entropy, noise entropy power, entropy power of the noise, maximum entropy for the power, entropy power of the received signal, entropy power of the sum of two ensembles, entropy powers, individual entropy powers, maximum entropy power of a sum, entropy of the maximum distribution, entropy of the transmitted ensemble, entropy of the white noise, entropy of an underlying stochastic process, maximum possible entropy for a power, have absolutely positively unequivocally NOTHING to do with thermodynamics, specifically the original entropy of Clausius or the ideal gas entropy of Boltzmann or the statistical mechanical entropy of Gibbs. The above usages are but a cesspool of misadopted terminological confusion.

Historically, to continue, the amount of 'Pandora's box' confusion, as French geneticist Antoine Danchin puts it, surrounding the falsely-assumed notion that Shannon entropy equals Boltzmann entropy is immense.[1] American evolutionary chemist Jeffrey Wicken, in 1987, cogently summarized things as follows (his *italics*, quote slightly rewritten, square brackets added):[8]

> "It is a **mistaken belief** that Shannon's function—called 'entropy' by namesake misadoption in information theory (Shannon and Weaver 1949)—has resulted in a true *generalization* of the Carnot-Clausius state function [dQ/T] treatment and the Boltzmann-Gibbs statistical [*H* function] treatment of the original [thermodynamic] entropy formulation of heat [Q], thus, in a sense, freeing it from disciplinary framework of thermodynamics for use in probability distributions in general—which is a major impediment to productive communication [in science]."

In addition, this is not the first time this 'mistaken belief' issue has been pointed out. In 1953, British electrical engineer and cognitive scientist Colin Cherry, in his *On Human Communication: a Review, a Survey, and a Criticism*, gave his reflective opinion:[9]

> "I had heard of 'entropies' of language, social systems, and economic systems and its use in various method-starved studies. It is the kind of sweeping generality which people will clutch like a straw. **[Shannon's] entropy is** essentially **a mathematical concept** and the rules of its application are clearly laid down."

Cherry here hits the nail on the head: Shannon's communication equation is a mathematical concept, plain and simple, NOT a thermodynamical concept. Clausius' 1865 state function heat differential equation, and Boltzmann's 1877 statistical reformulation of Clausius' equation, are physical concepts, derived from a combination of the 1824 Carnot heat engine and the 1798-1843 mechanical equivalent of heat, not from telegraph wire communication theory and cryptography, wherein Shannon's misaligned adoption of the term entropy is blanketed. This difference here should be obvious. What *per se* is 'noise entropy power'? Certainly this is not a thermodynamics term. None of Shannon's entropy-borrowed terms, for instance, are found in French thermodynamicist Pierre Perrot's 1994 *A to Z of Thermodynamics* dictionary. While a steam engine makes noise, and has a given horse power—or pony power as Scottish engineer James Watt originally called it—each heat cycle increasing entropy in the working body, there certainly is no such thing as noise entropy power in thermodynamics. Yet when one is 'clutching a straw', as Cherry sees things, it is very hard to let go.

Perrot's dictionary, to be frankly clear, does contain an one-page entry on 'information', wherein he states, in rather ambivalent or say encyclopedia-neutral format, that:[217]

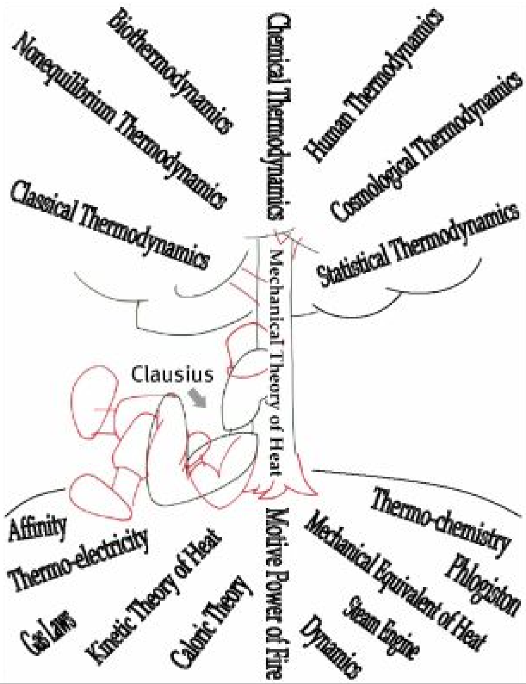
> "There is an *analogy* [between] an assembly of *N* particles distributed between states [and] the information content of a message comprising *N* symbols, each of which is subject to a probability p_i, expressed in bits per symbol, in the form of *H* [Shannon's entropy]. It [H] equals zero when the probability of each symbol is the same."

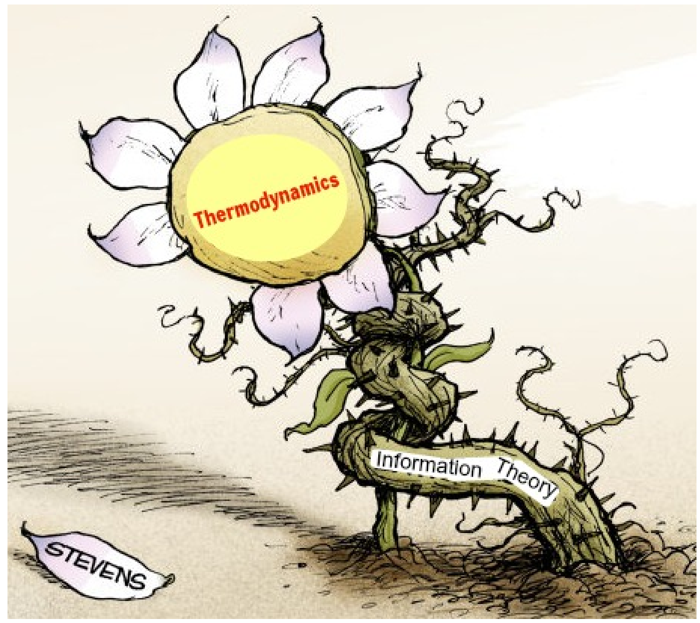
Thus, in France, the École Polytechnique birthplace of thermodynamics, there is a purported or rather dictionary summarized statement that there is an 'analogy' between the Boltzmann probability of states in a system model of entropy and the Shannon probability of symbols in a message model of information transmission (aka Shannon entropy)? The real question, however, is: is there any physical reality to the analogy? American anthropological neuroscientist Terrence Deacon answers the question as follows:[220]

> "The analogy [of Shannon entropy] to thermodynamic entropy breaks down because Shannon's concept is a logical (or structural) property, not a dynamical property. Shannon entropy, for example, does not generally increase spontaneously in most communication systems, so there is no equivalent to the second law of thermodynamics when it comes to the entropy of information. The arrangement of units in a message doesn't spontaneously 'tend' to change toward equiprobablity."

Here we see a situation where an anthropologist is more intuitively knowledgeable about thermodynamics than a thermodynamicist.

In any event, the fact that purported Shannon-Boltzmann analogies are being maintained in modern thermodynamics dictionaries gives indication to deepness of the roots of the *Shannon entropy equals thermodynamics myth* in modern science. These 'roots', however, are not of the roots of the tree of Clausius, below left, but are one of the roots of the *weeds*, using the language of American science historian Erwin Hiebert, in the beautiful garden of thermodynamics, below right:[121]





Left: the various branches and roots of thermodynamics; the trunk being German physicist Rudolf Clausius' 1865 *Mechanical Theory of Heat*.[218] **Right:** a depiction of information theory as one of the weeds in the garden of thermodynamics, in the language of American science historian Erwin Hiebert.[121]

Our focus herein, then, will be to investigate the weed-ridden roots of this so-called Shannon-Boltzmann 'analogy' and to explain and clarify fully, even to seasoned professors of thermodynamics and to authors of thermodynamics dictionaries—Perrot happens to be an associate of the author—that there is NO actual basis and factual reality to the analogy.

It should be noted at this point, in regards to Perrot's dictionary comment that 'entropy [Shannon] equals zero when the probability of each symbol is the same', that this 'equals zero' is NOT in any sense related to the entropy of thermodynamics, where specifically entropy is zero ONLY for chemicals in the pure crystalline state at absolute zero. This was explicitly stated in 1923 by American physical chemist Gilbert Lewis as follows:[188]

> "If the entropy of each element is some crystalline state be taken as zero at the absolute zero of temperature, every substance has a finite positive entropy; but at the absolute zero of temperature the entropy may become zero, and does so become in the case of perfect crystalline substances."

This is what is called the third law of thermodynamics.[219] Possible confusions with Shannon's *H* function ['entropy' or *uncertainty*] model of information-transmission should be noted here. The two, to be very clear, have absolutely NOTHING to do with each other. The 'Clausius tree' and the 'Hiebert garden' are analogies; the Shannon claimed-to-be *analogy* to statistical mechanics is but a mathematical delusion.

In 1954, Anglo-Dutch physicist Dirk ter Haar, in his *Elements of Statistical Mechanics*, argues firmly against any identification of information with thermodynamic entropy, as shown below (his *italics*):[10]

> "The relation between entropy and lack of information has led many authors, notably Shannon, to introduce 'entropy' as a measure for the information transmitted by telephone lines, and so on, and in this way entropy has figured largely in discussions in information theory. It must be STRESSED here that the **entropy** introduced **in information theory is *not* a thermodynamical quantity** and that the use of the same term is rather misleading."

We might think that this direct statement coming from a leading physicist—an editor of *Physics Letters* in fact—would have been enough to shut the entire illusionary Shannon-based thermodynamics campaign down? This, however, has hardly been the case. In fact, in the decades to follow entire 'schools' of thinkers attempting to argue the exact opposite—namely that the entropy introduced in information theory *is* a thermodynamical quantity—emerged: the late 1950s maximum entropy school of American physicist Edwin Jaynes and the more recent nearly incoherent so-called *infodynamics* school of Canadian zoologist Stanley Salthe, being two examples.[11] These schools, naturally enough, not heeding stern warning of ter Haar, have 'failed to be accepted by the majority of scientists.'[12]

Ter Haar's warning, however, was but a small paragraph buried deep in the back of a relatively equation thick book; hence, it is not surprising that his memo warning was not quickly assimilated. Perrot, in fact, seems to be completely unaware of ter Haar's 'it must be stressed' memo, hence the neutrality of his dictionary entropy on information.

By 1972, it had become a 'widespread belief', according to Swiss theoretical physicist Josef Jauch and American mathematician Julius Baron, that 'physical entropy used in thermodynamics is more or less related to the concept of information as used in communication theory', as they state in the opening of their article 'Entropy, Information and Szilard's Paragraph'. Jauch and Baron then devote fourteen pages to a fuller elaboration on ter Haar's point of view—namely that entropy in information theory is *not* a thermodynamical quantity—the abstract of which is as follows:[12]

> "The similarity of the formal expressions in the two cases has **misled many authors** to identify entropy of information (as measured by the formula of Shannon) with negative physical entropy. The origin of the confusion is traced to the thought experiment of Szilard, which we analyze herein."

Indeed, many authors, at present, are still being misled by the similarity of the two expressions. Jauch and Baron's article, in short, firmly argues against any identification of thermodynamic entropy, as defined by Clausius, with the information theory entropy, as defined by Shannon[59]

In 1999, American mechanical engineer and thermodynamicist Stephen Kline, in his book *The Low-Down on Entropy and Interpretive Thermodynamics*, specifically states that the two forms, Shannon and Boltzmann, are completely unrelated.[14] American molecular geneticist Thomas Schneider, since 2002, has had this very same Kline-cited memo posted online, at his Frederick National Laboratory for Cancer Research website, under headers such as 'Shannon entropy is a misnomer' and 'information is not entropy', wherein he devotes webpages of discussion on the confusion that abounds in his field surrounding this ongoing semantic muddling issue. Brazilian electrical engineer Erico Guizzo, who did his 2003 master's thesis, at MIT, on 'Claude Shannon and the Making of Information Theory', a detailed and personal interview look at early formation of information theory, also cites Schneider, stating that:[15]

> "Some think Shannon's quantity was **badly named**; thermodynamic entropy and Shannon's entropy are two different things."

Yes indeed some do think Shannon's function was badly named: nearly every fundamentally-educated physical scientist. Likewise, since 2006 the Wikipedia entropy article specifically notes that 'some authors, such as Schneider, argue for dropping the word *entropy* for the *H* function of information theory and using Shannon's alternative term *uncertainty* instead.'[16]

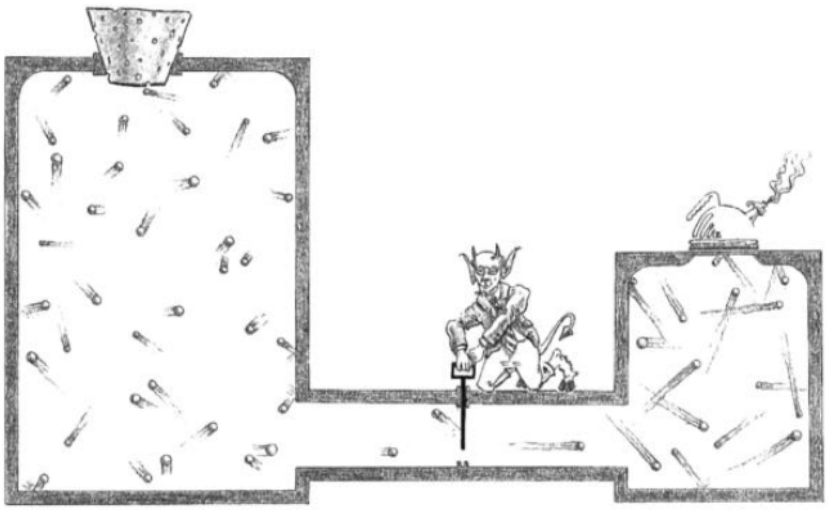
For some reason, however, these cogent calls of sanity are not loud enough—or possibly not clear or direct enough—and, as Danish information philosopher Niels Gregersen summarized things in 2003, 'the disagreements rumble on, even today.'[59]

One possible reason for this so-called *ongoing rumble* is that in addition to the above clarion calls of erudite reason by professional thermodynamicists, physicists, and chemists, new publications by less erudite thinkers, many tending to be mathematicians and non physical scientists, filled with erroneous viewpoint mis-representation, a twisting of things around, anachronisms, and false facts, etc., promoting the opposite point of view continue to be generated, possibly even in greater number. In addition, by no coincidence, a great many of these tend to be information theory based theories of everything.

A ripe example is American mathematician turned journalist Charles Seife, who in his 2007 book *Decoding the Universe: How the New Science of Information is Explaining Everything in the Cosmos, from Our Brains to Black Holes*—the title, of course, says it all—bends, twists, convolutes, mis-cites, falsifies facts, and distorts things together in a slipshod attempt to outline an 'information theory of everything'. Seife even goes so far to state that 'thermodynamics is just a special case of information theory', thus promoting the nearly upside down premise that information theory is the fundamental structure of thermodynamics, the newly framed so-called information law of the universe, meaning that *theory* now outranks *law*—flipping the scientific method upside down, as he would have it. At one point, however, to give Seife some credit, he does state the following:[145]

> "Shannon himself didn't concentrate on the tie between the abstract world of information and the concrete world of thermodynamics. But other scientists were consumed by [the] question. Was Shannon entropy truly related to thermodynamic entropy, or **was the similarity cosmetic?** Just because Shannon entropy—the measure of information—looks, mathematically, exactly the same as the Boltzmann entropy—the measure of disorder—it doesn't necessarily mean that the two are *physically* related. Lots of equations look the same and have little to do with each other; mathematical coincidences abound in science."

Hoorah! Finally some common sense. The issue couldn't be stated more clearly. The namesake entropy used by Shannon is but cosmetic, nothing more nothing less. Just because equations 'look' the same does not mean theory *are* the same. This is basic Math 101. Yet, in the end, Seife, being on the zeal tip, and writing a book geared towards, as Salon.com puts it, the 'liberal arts major and other right-brainers' (no disrespect intended here, but frankly entropy is a left-brain subject, or rather a *left-culture subject* as English physicist C. P. Snow defines things), doesn't listen to his own advice and his book is filled with incorrect statements such as 'Shannon entropy *is* a thermodynamic entropy' (his *italics*), 'entropy and information are closely tied to each other', 'entropy is, in fact, a measure of information' [this is, in fact, a misfact], that Shannon told the 'call your function entropy' Neumann anecdote to 'one of his colleagues at Bell Labs' [he told this to Myron Tribus while at MIT], among numerous other inaccuracies. To Seife's credit he does, however, give a pretty decent Maxwell's demon diagram (drawn by artist Matt Zimet), shown below, illustrating the hypothetical premise that a Maxwell's demon, with the supernatural ability to separate slow molecules from fast ones, has the supernatural power to reverse the second law, creating a temperature difference, that, say, could be used to boil water and thus operate a perpetual motion of the second kind machine, without the expenditure of work:[145]



Or as Scottish physicist James Maxwell put it in 1871:[184]

> "If we **conceive of a being** whose faculties are so sharpened that he can follow every molecule in its course, such a being, whose attributes are as essentially finite as our own, would be able to do what is impossible to us. For we have seen that molecules in a vessel full of air at uniform temperature are moving with velocities by no means uniform, though the mean velocity of any great number of them, arbitrarily selected, is almost exactly uniform. Now let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being, who can see the individual molecules, opens and closes this hole, so as to allow only the swifter molecules to pass from A to B, and only the slower molecules to pass from B to A. He will thus, without expenditure of work, raise the temperature of B and lower that of A, in contradiction to the second law of thermodynamics."

This demon argument, as we will discuss, is at the heart of information equals entropy myth.

Form argument

Is the similarity merely cosmetic? One of the main fuels that keeps sparking the ongoing rumble is what called the 'form argument', the simian view that since the Boltzmann and Shannon equations have similar mathematical *form*, they must thus be explaining the same underlying phenomena. Russian-born American mathematician and information theory zealot Anatol Rapoport, in 1976 Third Annual Ludwig von Bertalanffy Memorial Lecture, 'General Systems Theory: a Bridge Between Two Cultures', puts it like this:[197]

> "In thermodynamic terms entropy is defined in terms of the relation between energy and temperature. In communication theory entropy refers to the uncertainty associated with messages. **A more far-fetched connection is difficult to imagine**, but it has been conclusively demonstrated by the *mathematical isomorphism* between the two."

Indeed, that the entropy of Shannon is somehow related to the entropy of Clausius is, we might say, the most far-fetched supposition in the history of science. This apocryphal so-called connection between the two, contrary to Rapoport's biased view, however, has never been conclusively demonstrated. Herein, conversely, we intend to show, conclusively, that there is NO connection between the two.

In 2002 intelligent design book *No Free Lunch*, by American mathematician-theologian William Dembski, to exemplify further, he states 'information-theoretic entropy measure is mathematically identical to the Maxwell-Boltzmann-Gibbs entropy from statistical mechanics'. Everyone knows, however, that intelligent design books are nearly-childlike in their arguments. Perhaps we can excuse Dembski here. Yet, ironically, the source for his essentially meaningless statement, the so-called mathematical identity proof (similar to Seife), however, is no other than Boolean algebra computer prodigy Claude Shannon himself—hailed, at the age of 23, by Raytheon founder Vannevar Bush as being 'apparently, a genius'.[27] In his 1968 *Encyclopedia Britannia* article 'Information Theory' Shannon wrote the following overview:[17]

> "The formula for the amount of information is identical in form with equations representing entropy in statistical mechanics, and suggest that there may be *deep-lying connections* between thermodynamics and information theory. Some scientists believe that a proper statement of the second law of thermodynamics requires a term related to information. These connections with physics, however, do not have to be considered in the engineering and other [fields]."

The form argument—that seems to get repeated *ad nauseam* by information theorists—the notion that if two equations are of the same 'form' (shape) then they must have an underlying 'deep' connection, tends to be thrown about as some kind of assumed *proof*, mathematical or scientific, that information theory is based on thermodynamics. The steps of physical proofs, however, are completely different in composition than the steps of mathematical proofs. To give an idea of the absurdity of the form argument, in regards to Shannon entropy equating to Boltzmann entropy because they have the same *form*, it is like saying that because Beckhap's law, which says that beauty is inversely proportional to brains:[18]

$$\text{beauty} \propto \frac{1}{\text{brains}}$$

has the 'form' as Boyle's law, which says that pressure is inversely proportional to volume:[19]

$$P \propto \frac{1}{V}$$

that there must be some *deep* underlying connection between the two of them, beauty and pressure, and brains and volume, respectively. This is what is called the fool's argument. Equations that have the same form, as noted by Rapoport, are called *mathematical isomorphisms*, a fact that in and of itself is nothing special.[16] As American engineer Myron Tribus put it his 1987 commentary of Shannon's use of the *form argument* to justify calling his communications formula by the name entropy:[57]

> "Just because a function appears in two different fields **does not mean** that the fields are analogous. For example sin (*x*) appears in both surveying and in electrical engineering and no one thinks that therefore the two fields are logically the same."

French geneticist Antoine Danchin, from his 2002 chapter subsection 'Wiener's Entropy and Shannon's Entropy', puts it like this:[1]

> "The entropy of a perfect gas can be put into equations in a *form* that is almost identical with that given by Shannon's information. This similarity between Shannon's formula, expressing the information contained in a family of transmitted alphabetic texts as a logarithmic law $\left(\sum p_i \log_2 p_i\right)$, and Boltzmann's equation, which calculates the entropy of a set of theoretical moving objects bouncing off one another $(S = \log W)$, **has been misused**."

Indeed, how can anyone confuse the *entropy* of a perfect gas with the *uncertainty* in the reception of a letter symbol in a telegraph signal transmission? Yet, ironically, this confusion has been maintained for some six decades now! As we will come to see, the source of this disjunct confusion has to do with a rather peculiar mixing of German physicist Werner Heisenberg's 1927 uncertainty principle with Scottish physicist James Maxwell's 1867 hypothetical Maxwell's demon thought experiment, in the particular case of a one molecule two-compartment system.

The *misuse* of the form argument in genetics, Danchin's research field, is particularly ripe, being firstly that the jump from the transmission of alphabetic texts (26 letter English alphabet) to the transmission of genetic code (4 letter base sequence alphabet), is an easy-step conceptual inlet into theory formation, one that many less discerning minds will be fast to peruse, often with end goal aims to solve the famous second law disordering versus evolution ordering paradox, thus becoming the new Darwin, so to speak, and also secondly because Shannon, in 1939, on the misaligned suggestion his mentor MIT professor Vannevar Bush, did his doctoral dissertation, entitled 'An Algebra for Theoretical Genetics', on a mixture of, supposedly, Mendelian inheritance and relativity, which never panned out as anything of lasting value, but which invariably worked to get his name into the genetics game.[27]

Form arguments are also particularly ripe in economic thermodynamics. One example, to give some comparison, being American mathematician Harold Davis' 1941 modelling of a person's budget in the differential form:[161]

$$dI = dS + dE$$

where *dI* is an income differential, *dS* a savings differential, and *dE* an expenditure differential, which, according to Dutch mathematical economist Johannes Lisman, is an attempt to formulate an economic first law of thermodynamics:[162]

$$dQ = dU + dA$$

where dQ is a differential amount of heat added to a system, dU is the change in the internal energy of the system, and dA is the work done by the system on the surroundings. The derivation of the latter involves some three-hundred years of underlying mathematical and experimental physics justification, rooted in the works of some of the great minds of all time: Isaac Newton, Gottfried Leibniz, Gustave Coriolis, William Hamilton, Carl Jacobi, and Leonhard Euler, to name a few, and detailed derivation, filled with footnotes, such as how U the internal energy is a sum of the present state *kinetic energy,* i.e. velocity energy of the particles, of the system plus the *ergal*, i.e. the work done by the forces of the universe in bringing the particles of the system to their present potential energy positional state configuration.[163]

Jumps from the latter (first law) to the former (economic theory), such as done by Davis, tend to be ball park intuitional jumps—or as Danchin puts it, in regards to the Shannon entropy and Boltzmann entropy *isomorphism* comparison:[1]

> "**There** [is] **no theoretical justification for this** [isomorphism] **approach**, just intuition."

While intuition works in some cases and while there may be some argument in the supposition, for instance, that personal savings have correlation to the internal energy of one's reactionary state of existence, these gleanings, however, by no means, justify the argument that all equations of the generic mathematical *form*:

$$dX = dY + dZ$$

are expressions of the first law of thermodynamics. It is the same with the case of Shannon's H function, namely that not all equations of the generic mathematical *form* of logarithms are measures of entropy or of the second law of thermodynamics.

In economics, to point out, there are so many of these types of baseless form arguments, that in 1983 American economist Paul Samuelson, who would frequently receive papers containing form arguments in his monthly mail, introduced the term 'economic isomorphisms' to categorize the use of such polemical arguments in the subfield of economic thermodynamics, as he summarizes in his chapter appendix section 'Thermodynamics and Economic Isomorphisms', wherein he seems to think that, although he is generally against such formulations, there is right way and wrong way in making thermodynamic isomorphisms, in economics.[164]

In any event, to continue, possibly we can excuse Shannon, Dembski, and Seife in their misuse of the form argument since they were extrapolating outside of their respective fields, communications, mathematics, and journalism, respectively. Yet, when we find the statement 'only recently has entropy been widely accepted as a form of information' being taught in 2008 at MIT, the world's leading technical university, specifically as described in an OpenCourseWare course entitled 'Information and Entropy', one is a bit taken back. Are we teaching false information in our world's leading universities? Certainly this wouldn't be the first time. Schneider, for example, posts this courseware note on his website as an example of erroneous mis-information.[21] The course, conceived in *circa* 2000 by electrical engineer Paul Penfield, launched in 2003, and co-taught with quantum information theorist Seth Lloyd, has the following course objective, which Penfield tells to his students when the course starts:[15]

> "One of the goals of the course is to study the second law of thermodynamics as a kind of information processing. Information and entropy are related in an intimate way. They are the same thing but in different contexts."

Supposedly, now, according to the views of Penfield and Lloyd, engineers no longer need to take their core Clausius-based *Mechanical Theory of Heat* thermodynamics courses anymore, all one needs is his or her handy-dandy Shannon-based *Mathematical Theory of Communication*. The keen insight of Goethe seems apt here: 'we do not have to visit a madhouse to find disordered minds; our planet is the mental institution of the universe.'

The one with the disordered mind here, to clarify, is Seth Lloyd. In his 2006 book *Programming the Universe*: *a Quantum Computer Scientist Takes on the Cosmos*—a modern treatise on how 'not' to write a science book—he makes up his own version of the second law, namely: 'information never decreases', explains that we no longer need the absolute temperature scale, namely because 'temperature is [now measured as] energy per bit' (we sure would like to see this thermometer), makes near preschool-like comment such as 'heat has lots of entropy' (technically an *inexact* differential of heat δQ equals the product of the absolute temperature of the boundary of the system and an *exact* differential of entropy dS)—which akin to a comment such as 'water has lots of H_20'—and historically misattributes scientist after 19th century scientist as having theorized about entropy in terms of bits and information. Lloyd states, for instance:[221]

> "Maxwell, Boltzmann, Gibbs, and Planck discovered that entropy is proportional to the number of bits of information registered by the microscopic motion of atoms."

Lloyd gives page after page of these types of false historical misattributions. American anthropological neuroscientist Terrence Deacon comments on this:[220]

> "Lloyd writer almost as though they had modern conceptions of computing and information, and conceived of thermodynamic processes as intrinsically a form of information processing. Intended as a heuristic caricature, this way of telling the story nonetheless **misrepresents history**."

Historical misattributions, in information theory publications, to note, are common, especially in over-zealous information theory platformed agenda writings, and especially in those attempting to argue for information theory based theories of free will, as is the case with Lloyd.

In the 2011 book *Free Will: the Scandal in Philosophy*, by American physicist Robert Doyle, to give another similar example, we find the misattribution statement: 'Kelvin's claim that information must be destroyed when entropy increases would be correct if the universe were a closed system.'[223] In review of his book, in 2012 email discussions, the author queried Doyle about this: "Kelvin never 'claimed that information must be destroyed when entropy increases'; neither is 'information mathematically the opposite of entropy'; you seem to have the casual habit of bending and twisting things around to suit your agenda, each of which in the long run is eroding away your credibility." To which Doyle replied: 'You are quite right that Kelvin did not use the term 'information'. I used it (anachronistically, to be sure) in my introduction chapter. I guess we all twist things sometimes. Thanks for the critical reading.'[75] No we don't all twist things around sometimes.

Lloyd, to continue with the MIT course example, is in fact so ignorant of thermodynamics—he states that his sole knowledge of thermodynamics comes from one statistical mechanics class he took under American physicist Michael Tinkham—that he misattributes Hungarian-born American physicist Leo Szilard's famous 1922 article 'On the Decrease of Entropy [in a Thermodynamical System] by [the Action of] Intelligent Beings', accepted by the University of Berlin in 1925 as his habilitation, as being a 'famous letter' of Scottish physicist James Maxwell.[221] To clarify for Lloyd, in case he happens to read this article, Maxwell's famous letter was entitled 'Concerning Demons' and was sent as un undated, *circa* 1876, letter to his associate Scottish physicist Peter Tait, which contains the following:[222]

Concerning Demons

1. Who gave them this name? Thomson.
2. What were they by nature? Very small BUT lively beings incapable of doing work but able to open and shut valves which move without friction or inertia.
3. What was their chief end? To show that the 2nd Law of Thermodynamics has only a statistical certainty.
4. Is the production of an inequality of temperature their only occupation? No, for less intelligent demons can produce a difference while stopping all those going the other way. This reduces the demon to a valve. As such a value him. Call him no more a demon but a valve like that of the hydraulic ram, suppose.

From Morse code to bitropy

The jump from Morse code to Boltzmann entropy is still mind-boggling, when looked at in retrospect, in regards to how this incongruous bridging resulted. In an effort to remedy this near-century-long ongoing befuddled confusion—in other words, to burn the bridge—an official proposal will be made herein, as discussed at the end of the article, to change the name of Shannon's uncertainty function, symbol *H*—aka *Shannon entropy*—to ***bitropy***, a new replacement upgrade term modification, short for 'bit-entropy', 'binary digit entropy', or 'bi-tropy', depending on phonetical interpretation preference, which translates, in etymological step upgrade terms, as the transformation (-*tropy*, from the Greek *τροπή*, meaning 'turn' or 'change') of a 'choice', in the *uncertain* reception of a transmitted bi-variable symbol message, between two (*bi*-) *alternatives* (bits), into information, of the Boolean algebra binary logic variety.

Terminology reform in information theory is long overdue. As American applied mathematician, plasma physicist, and electrical engineer Harold Grad put it in 1961, after coming across the term 'entropy' being used in information theory:[107]

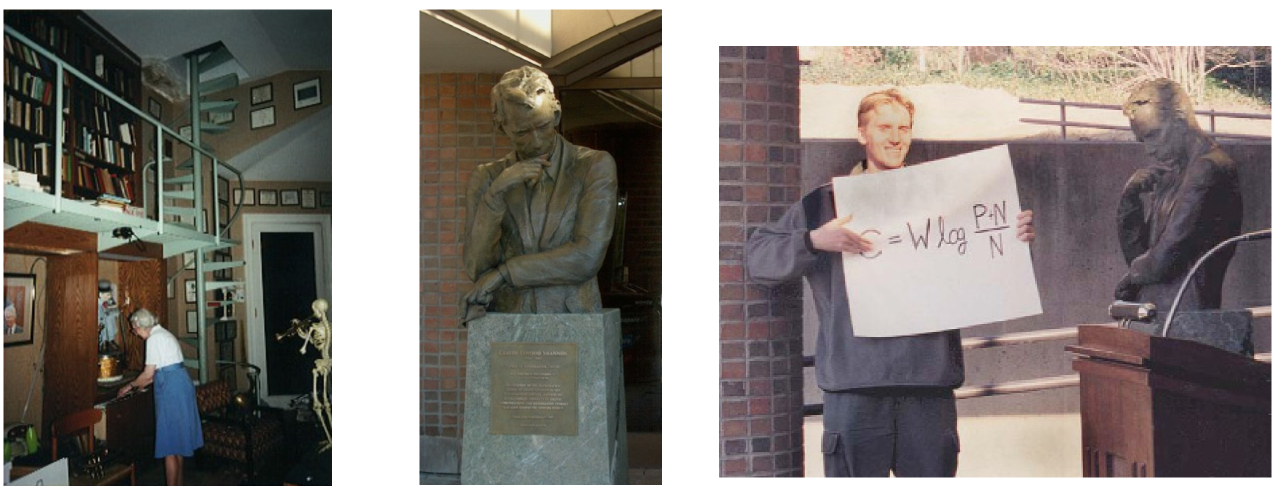
> "One of the reasons for the bewilderment which is sometimes felt at an unheralded appearance of the term *entropy* is the superabundance of objects which bear this name. The the **lack of imagination in terminology** is confusing."

Indeed, the use of the same name for two completely unrelated concepts is confusing and continues to be confusing up to the present day. American systems ecologist Edward Goldsmith, in his 1998 appendix section on entropy, puts it like this:[204]

> "Shannon's information theory, while perfectly acceptable so long as it is applied to the field of communications for which it was designed, has become the object of a cult, worshipped as the key which will unravel the secrets of the universe, but has only served to **confuse everybody** after being hailed as a great scientific discovery that would, among other things, provide a means of measuring biospheric complexity or organization."

This certainly captures Lloyd's 'a quantum computer scientist takes on the cosmos' mindset well.

One of the underlying reasons for this 'confusion', everybody is symptom to, has to do with the fact that the historical origin of the confusion is rather intricately elaborate, in some aspects 'secret', and person-intertwined, involving advanced scientific concepts, which themselves are, in some cases confusing, namely: the second law, Maxwell's demon, wave function collapse, quantum mechanics, particle physics, cryptography, Brownian motion, communication engineering, transistor operation, the Heisenberg uncertainty principle, among others, not to mention conflicting statements, by Shannon himself, concerning the details of the etymological adoption of the term he became so famous for that he in fact named his Winchester, Massachusetts home, 'Entropy House', after it—a glimpse inside of which is shown below, left—a stately home, originally owed by Thomas Jefferson's great granddaughter:[27]



Left photo: a glimpse inside of Shannon's self-christened 'Entropy House', in Winchester, Massachusetts; his second wife Betty, whom he married in 1949, shown in the photo.[199] **Right photos:** from the 2001-dedication of the Claude Shannon statute, by sculpture Eugene Daub, EECS Building, University of Michigan. The right photo shows graduate student Kevin Holt displaying Shannon's capacity formula for the white Gaussian noise channel, as inscribed on the 'sheet' in the statue's left hand, where *C* is the number of bits per second that can be reliably transmitted with bandwidth *W* and power *P* when combatting noise power *N*.[201]

In Shannon's self-defined Entropy House, is his famous 'toy room', which includes things such as robotic juggling clowns, computerized chess playing machines, robotic hands, a probe light video studied casino roulette table, a rocket-powered Frisbee, a mechanical maze-solving mouse, among other things, wherein, working together with American child prodigy mathematician turned gambling theorist Edward Thorp, the first wearable computer was invented, a cigarette pack sized casino betting facilitative prediction device, consisting of twelve transistors.[205] The grounds of the Entropy House, moreover, has equipment such as a ski lift that transported family members from the house to the lake; on the lake Shannon could sometimes be seen walking on water, wearing his outsized foam shoes. Oddly, then, as we will see in later interviews, the origin of the namesake for this vast Edison-like amusement park, i.e. 'entropy', remains a blur to Shannon, whenever questioned about this.

The photos to the right are from 2001 Shannon Statue unveiling at the University of Michigan, at the west entrance to the EECS building, one of six statutes dedicated throughout the United States, including Gaylord, Michigan, Lucent Bell Labs, Murray Hill, New Jersey, ATT Shannon Labs, Florham Park, New Jersey, MIT, Cambridge, Massachusetts, and the University of California, San Diego, California, designed by sculptor Eugene Daub. If a picture is worth a thousand words, the fact that the scratch note 'sheet' in the statue's left hand has formula for the white Gaussian noise channel:[201]

$$C = W \log \frac{P+N}{N}$$

where C is the number of bits per second that can be reliably transmitted with bandwidth W and power P when combatting noise power N, and NOT Boltzmann's H theorem, as many—such as Lloyd and Doyle—would like to believe, says it all.

John Nash syndrome

The recent 2009 investigative book *Claude E. Shannon: Toys, Life and the Secret History of His Theory of Information*, by German media studies researcher Axel Roch, gives way to the notion that there is a somewhat secret history to the origins of Shannon's information theory and by consequence the nature of his adoption of the name entropy for his H formula of uncertainty.[186] While some of this so-called 'secrecy' has to do with WWII and certain documents, e.g. those dealing with cryptography, being classified, in the mid-1940s; another part of this secrecy seems to have to do with the fact that Shannon, during his late 1940 to early 1941 stay at Princeton, while he was pressurizingly-working alongside some of the biggest minds of the century, including Einstein, Gödel, and Neumann, the window when he was advised by Neumann to use the name *entropy* for his new H formula, nearly cracked up.

During this period, Shannon's new wife Norma Levor, pictured below right, a Radcliffe coed turned Hollywood screen writer, whom he had recently married in 1939, during this pressurizing period, tried to convince him to see psychiatric help. He refused. During one violent argument, in June 1941, Norma ran all the way to Princeton Junction and took the train to Manhattan.[27] She never returned to Princeton and did not see Shannon again for another twenty-two-years.[200]


Left photo: Shannon, 1939, in a Piper Cub, when he gets his pilot's license, about to take Norma on her first plane ride. **Right photo**: Shannon's first wife Norma Levor, 1949, second to left, with Adrian Scott, left, and Jeannie Lees, Bobbie Lees, and Annie Scott, respectively, who left Shannon in June 1941, shortly following the Neumann 'call your function entropy' anecdote, because he was becoming mentally disturbed, of the John Nash variety, as she would recall later.[200]

Norma was a bit of peculiarity herself. In her 2004 book *The Red and the Blacklist: the Intimate Memoir of a Hollywood Expatriate*, she gives the following glimpse into her mindset:[202]

> "I was more excited meeting Picasso than I was in Princeton in 1940 when my then husband, Claude Shannon, introduced me to Einstein. Picasso was an artist. Picasso was a communist. Picasso was us."

We point this out here because these late fall 1940 months at Princeton is the window when the famous 'call your function entropy' conversation with John Neumann took place, which Shannon, in 1961 claims to have occurred, according to the published interview notes of American engineer Myron Tribus, but which in the decades to follow, in other interviews, would be in blurry denial about.

In reflection on this tumultuous period, Shannon's employer Warren Weaver wrote to Vannevar Bush, Shannon's MIT dissertation advisor:[198]

> "For a time it looked as though [Shannon] might crack up nervously and emotionally."

In 1963, during a chance visit to Cambridge, Massachusetts, Shannon then being on the faculty at MIT, the two, Shannon and Norma, got together for the first time since Norma's split from Princeton. The first words Shannon spoke, she relates, were, 'why did you leave me?' to which she replied, 'you were sick and wouldn't get help'.[202] Moreover, in a 2009 YouTube video, she elaborates on this sickness, by comparing Shannon to American mathematician John Nash of *A Beautiful Mind*, a reference to paranoid schizophrenia—a disturbance that she says was so pronounced that she decided she would not have any children with Shannon.[203]

Certainly, as Aristotle said, 'there was never a genius without a tincture of madness', and no-doubt Shannon was a genius and no-doubt he may have, like all geniuses, been a bit mad in some sense, at some period in his existence. The focus here, however, is not a jab at Shannon's eccentricities and possible mental breakdowns, but rather why he dragged thermodynamics terminology, like weekend baggage, into his communications theory. The supposition we will enter here is that possibly Shannon, in his later years, mentally repressed these early *circa* 1940 tumultuous and tension-filled years, in a sense blocking out the memory, a common fix many use to remedy traumatic situations.

Hence, to conclude, we point out here that during the period when Shannon was formulating his communications theory and deciding on the new name for his new *H* formula—intelligence, uncertainty, choice, or entropy—he was also, it seems, suffering from John Nash syndrome.

Asterisk usage

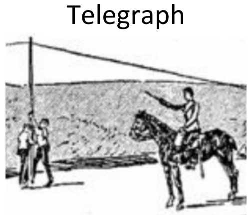
Because there has been no terminology reform, since the days of Shannon, some authors presently are forced to used asterisks * when first mentioning the name 'Shannon entropy' to clarify possible confusion with the entropy of thermodynamics. This is further compounded by the fact that thermodynamics authors are now, in certain discussions, forced to use redundant term 'thermodynamic entropy', to clarify that one is not speaking of information entropy, which is a nearly inane situation, to say the least—possibly akin to a chemist speaking of a 'chemical atom' as contrasted with an atom, as though the two were not the same. An example of asterisk usage is found in American biochemist and intelligent design advocate Stuart Pullen's 2005 book *Intelligent Design or Evolution?*, where he gives the following asterisk footnote at the first usage of the term Shannon entropy:[174]

> * Shannon entropy should **not be confused with the term entropy** as it is used in chemistry and physics. Shannon entropy does not depend on temperature. Therefore, it is not the same as thermodynamic entropy. Shannon entropy is a more general term that can be used to reflect the uncertainty in any system. Thermodynamic entropy is confined to physical systems.

Historically, the way in which term confusion in science is remedied is name change. The case in point here is the conclusion that Shannon entropy needs a new agreed upon name modfication.

To continue, Morse code, which Shannon as a boy in *circa* 1926 sent along the barbed wired fence to communicate via pulse coded messages to his neighborhood friend, according to modern international code standards, is composed of three main elements: one a short mark, dot or "dit" (·) or "dot duration" that is one unit long (1 in binary), a longer mark, dash or "dah" (–) that is three units long (111 in binary), and an inter-element gap between the dots and dashes within a character (0). Morse code can be transmitted in a number of ways: originally as electrical pulses along a telegraph wire, but also as an audio tone, a radio signal with short and long tones, or as a mechanical or visual signal (e.g. a flashing light) using devices like an Aldis lamp or a heliograph, such as shown below:

Telegraph



Audio

Radio

Visual

Ways of transmitting Morse code, dots (·) or dashes (–), and or binary code (1s or 0s): telegraph, audio, radio, or visual. The reader should note here that NONE of this has to do with heat, transforming from a hot to a cold body, but rather are only variations of human-designed methods of communication.

The first-ever transmission of Morse code was the message 'What hath God wrought', a phrase from the Book of Numbers (23:23), transmitted by American inventor Samuel Morse on 24 May 1844, to officially open the Baltimore-Washington telegraph line, and is shown below in both Morse code and binary code of the 8-bit ASCII format:

W	h	a	t
.--	....	.-	-
0101 0111	0100 1000	0100 0001	0101 0100

h	a	t	h
....	.-	-	....
0100 1000	0100 0001	0101 0100	0100 1000

G	o	d
--.	---	-..
0100 0111	0100 1111	0100 0100

W	r	o	u	g	h	t
.--	.-.	---	..-	--.	....	-
0101 0111	0101 0010	0100 1111	0101 0101	0100 0111	0100 1000	0101 0100

In regards to the present topic, we might well rephrase Morse's telegraph message as 'What hath Shannon wrought', in regards to the Pandora's box he broached and the wrath of intellectual destruction that his ill-chosen entropy namesake adoption has caused. Rule number one in science: never use the same *name* for two different functions. Rule number two: never use the same *symbol* for two different functions. Rule number three: never use both the same *name* and the same *symbol* for two different functions. Shannon broke all these rules and we are all now paying the price.

The take away point to note here, in regards to the present article, is that none of these message-coded linear signal *distributions*, i.e. strings of "dits" (·) or "dahs" (–) or 1s or 0s, representing words, sent along a telegraph cable (current), through sound waves (pressure variations), through radio waves (3-300 meter electromagnetic waves), or through visually means (380-750 nm electromagnetic waves), are *probability distributions* of microscopic quantum states and or movements of atoms and molecules in a volumetric region of space. Said another way, as American engineer Myron Tribus defines Shannon's *H* function, the 'measure of the uncertainty in the mind of someone about to receive a message' is NOT entropy.[57] Said a third way, from the 2010 *Handbook of Data Compression*, the 'number of yes/no questions needed to reach the answer to some question' is NOT entropy.[155] While thermodynamics may indeed be a game to some—American science writer Isaac Asimov's 1970 game version of thermodynamics, shown below, being one popular example:[156]

Prologue
You have to play the game (thermodynamics governs the universe)

Laws
1) You can't win (first law)
2) You can't break even (second law)
3) You can't quit the game (third law)

it is certainly not a game of 20 questions, as Shannon would have us believe.[156]

In plane speak, distributions of moving atoms are NOT the same as distributions and probabilities of reading strings of current pulses. This is where the confusion has always resided in the nearly delusional ventriloquist idea Shannon entropy is Boltzmann entropy (or Clausius entropy)—namely people lost in the fine print of the details of the respective equations and also barred from complete understanding by a thick interdisciplinary divide between three densely separate fields of study: communications/electrical engineering, chemical/mechanical engineering, and statistical physics/statistical mechanics.

To continue, in 1932, at the age of 16, Shannon entered the University of Michigan, where he took a mathematics course that introduced him to binary algebra—a type of input-output logic based on 1s and 0s—developed by English mathematician George Boole, as published in his 1854 book *An Investigation of the Laws of Thought: on which are Founded the Mathematical Theories of Logic and Probability*. This is from where Shannon gleaned his first terminology outlines for his newly developing transmission of information theories. Boole states, for example:

> "They who regard the phenomena with which we are concerned in this inquiry as the mere successive *state* of the thinking subject devoid of any casual connection, and they who refer them to the *operations* of an active **intelligence**."

The term 'intelligence', used here, as Shannon would later comment, in a 1939 letter to his PhD advisor electrical engineer Vannevar Bush, was his first tentative namesake for his newly burgeoning H formula for the transmission of dits and dahs theory, or what would soon become—through his pioneering work—the probabilistic transmission of 1s and 0s as *information* theory. The term 'intelligence' was also the term Swedish-born American electrical engineer and Bell Labs employee Harry Nyquist used in his 1924 'Certain Factors Affecting Telegraph Speed', the opening abstract of which is as follows:[194]

> "In considering methods for increasing the speed of telegraph circuits, the engineer is confronted by the problem of transmitting over a circuit the maximum amount of **intelligence** using a given frequency range, without causing undue interference, either in the circuit being considered or from that circuit to other circuits."

American science biographer William Poundstone points out that in his early 1940s writings, Shannon favored Nyquist's term:[27]

> "As he developed these ideas, **Shannon needed a name** for the incompressible stuff of messages. Nyquist had used *intelligence*, and Hartley had used *information*. In his early writings, Shannon favored Nyquist's term."

The name Hartley here is a reference to American electronics researcher Ralph Hartley's famous 1928 article 'Transmission of Information', that Shannon also read in college, discussed further below. If Shannon would have been keen enough, at this point, to simply make a portmanteau of these two terms, intelligence + information, such as, for example, *intelliformy*, instead of adopting the term 'entropy' from physics, as he did, we would not be in the terminology mess we are presently in.

In 1932, the very same year that Shannon, as a college freshman, was studying the work of Boole, the newly-emigrated to America and recently-minted PhD chemical engineer, mathematician, and former child prodigy John Neumann published his *Mathematical Foundations of Quantum Mechanics*, wherein he argued, by means of a thought experiment involving measurements of spin observables, that the following formula is the quantum mechanical equivalent of thermodynamic entropy:[165]

$$S = -k\mathrm{Tr}(\rho \ln \rho)$$

where k is the Boltzmann constant, Tr denotes the trace, and ρ is the density matrix; which can also be re-written in the following form:[166]

$$S = -k \sum_{i=1}^{n} \lambda_i \log_e \lambda_i$$

where λ is the percentage of N ideal gas molecules in a pure state one, $(1 - \lambda)$ the percentage of molecules in pure state two, inside a rectangular box separated by a hypothetical semi-permeable membrane. This derivation, to note, was an extension of his earlier 1927 article 'Thermodynamics of Quantum Mechanical Assemblies', wherein he associated an entropy quantity to a statistical operator.[167] This article, in turn, has connection to Hungarian-born American physicist Leo Szilard's 1922 article 'On the Decrease in Entropy in a Thermodynamic System by the Intervention of Intelligent Beings', wherein he derives the result, based connectively on the 1905 thermodynamics of Brownian motion work of German-born American Albert Einstein, that the following equation is the entropy dissipation that occurs in the memory processing act of an 'exactly informed' Maxwell's demon:[41]

$$S = k \log 2$$

It remains to be determined exactly when Neumann read Szilard's 1922 article, being that it was not formerly published in a journal (in German) until 1929. It is known, however, that the two were personal friends; having in 1930, for example, taught a theoretical physics seminar together with Austrian physicist Erwin Schrodinger. In any event, in Neumann's 1932 *Mathematical Foundations of Quantum Mechanics*, Szilard's work is fully acknowledged, although it remains to be discerned as to what part of the above derivation is Szilard's and what part is Neumann's, particularly in regards to bi-compartment piston and cylinder semi-permeable membrane conception.

Whether or not Neumann's quantum thought experiment derived entropy here is 'thermodynamical', to note, has become a matter of some debate in recent years, following the publication of Israeli science philosopher Orly Shenker's 1999 article 'Is $-k\,\mathrm{Tr}(\rho \log \rho)$ the entropy in quantum mechanics?'.[165] This only adds further disconnection between Shannon entropy and thermodynamics, being that Neumann, as we will discuss further, is the sole person behind entropy equal information myth.

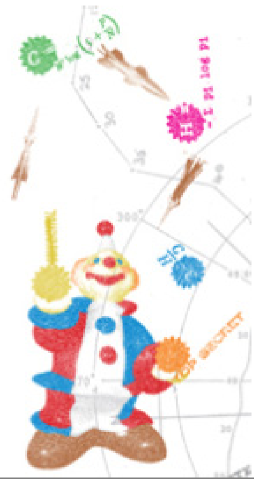
The reasoning behind the thought experiment, in Neumann's perspective, is that he wanted to understand the quantum mechanical origin of irreversibility of the *measurement process*—in connection to the nature of the collapse of the wave function.[165] Certainly a venerable aim, in any case.

The takeaway point to note here is that Neumann's quantum mechanical thought-experiment derived entropy has the same logarithmic isomorphic *form* of the information transmission equation that Shannon would come to formulate in the decade to follow (1945), based on previous telegraphy theory logarithm ideas of American electronics researcher Ralph Hartley (1928), and on Neumann's 1940 advice call this new equation by the name 'entropy'.[168] A sea of intellectual confusion has been the result.

In 1936, Shannon graduated from the University of Michigan with two bachelor's degrees, one in electrical engineering and one in mathematics—which, by coincidence, is similar to the author who also graduated from the same school, also with two bachelor's degrees, one in electrical engineering and one in chemical engineering, and also studied the same Boolean algebra based coding theory, specifically *Introduction to Digital Logic Design* (1993) by American electrical engineer and computer scientist John Hayes, as did Shannon—or more correctly as Shannon single-handedly invented; this kinship possibly being one of the reasons for the extensiveness of the current article: a cleanup job, one might say, or 'semantic house-cleaning', as American biochemist Jeffrey Wicken said, of one of the 20th century's greatest mars to the field of engineeing.[8] Hayes, in the 'Origins' subsection of his chapter on logic elements, gives the following historical on what exactly Shannon did:[22]

> "Boolean algebra is named after the self-taught English mathematician George Boole (1815-1864), whose influential 1854 book *The Laws of Thought* showed for the first time how to reduce human reasoning (logic) to a symbolic form resembling ordinary numerical algebra. Boole used the numbers 1 and 0 to symbolize the logic values true and false, respectively, and a binary variable symbol such as x to represent true-or-false statements, which is called a *proposition* in this context. Examples of propositions are '*A* is *B*' and '*A* is not *B*'. If x symbolizes a proposition such as '*A* is *B*', then $x = 1$ indicates that the proposition is true, while $x = 0$ means it is false.
>
> Under the name *propositional calculus*, Boole's algebra becomes one of the foundation stones of the mathematical theory of logic. In the late 1930s, mainly as a result of the work of Claude Shannon, an MIT graduate student in electrical engineering, the same algebra was seen to provide the theory needed for the analysis of digital circuits built from electromechanical relays [Shannon, 1938]. The two natural states of a relay switch, on and off, are the analogs of the true and false values of propositional calculus, and can similarly be represented abstractly by 1 and 0. Such switches are also combined into circuits that are the counterpart of propositions in mathematical logic."

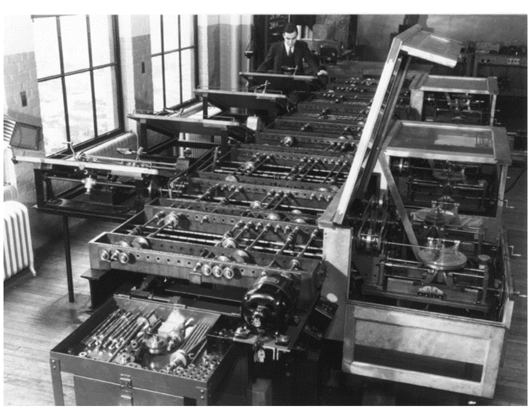
The author—the possessor of a near four-hundred book thermodynamics library—also has kinship with thermodynamics; hence the acuteness with which he sees the ridiculousness with which less-informed thinkers, ignorant of either electrical engineering, thermodynamics, or both, bandy about down the publication highway juggling Shannon in one hand and Clausius in the other like a circus clown at a Macy's Day Parade, tripping over their own feet while being fixated googly-eyed on the spotlight, fueled by either the laughter and or applause, depending, of the crowd—some of the calculated results being so far off the rails of reasonability as to make the head spin.[23]

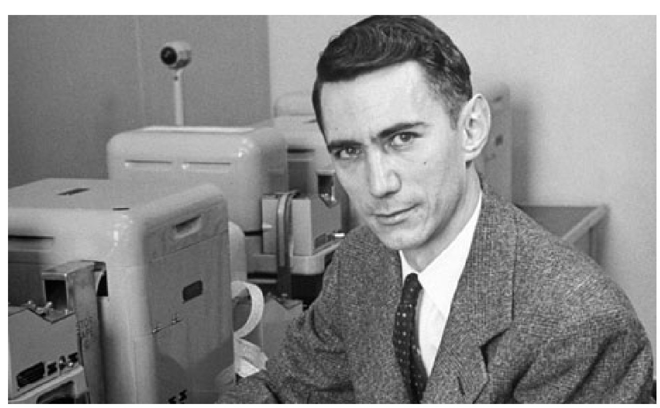


Left: cover design section from the 2009 book *Claude E. Shannon: Toys, Life and the Secret History of His Theory of Information*, by German media studies researcher Axel Roch, which depicts the Shannon equation clowning around effect very well.[186] **Right:** Shannon's mechanical juggling clowns, the operation of which can be watched in video.[205]

To continue, during this University of Michigan period Shannon gleaned the sharp insight that Morse code based telegraph communication methods could be made more efficient if the sending of dots and dashes were reformulated in terms of binary digits, 0s and 1s, respectively, and if both the coding and decoding of these digital messages and the logic gate circuit design that would process these signals were both written in the mathematical language of Boolean algebra—very clever indeed, especially for a 21-year-old.

Shannon then accepted a research assistant position at the MIT electrical engineering department. The position allowed him to continue studying toward advanced degrees while working part-time for the department. The work in question was ideally suited to his interests and talents. It involved the operation of the Bush differential analyzer, built by American analog computer engineer Vannevar Bush—the first person to whom Shannon, as mentioned, first opened up to about his burgeoning communication of intelligence theories—shown below, the most advanced calculating machine of that era, which solved by analog means differential equations of up to the sixth degree:





A *circa* 1930 photo of the Bush differential analyzer at MIT, worked on by Shannon.	A 1951 photo of Shannon, three years after the publication of his *entropy*-named theory of information.

The work required translating differential equations into mechanical terms, setting up the machine and running through the needed solutions for various initial values. In some cases as many as four assistants would be needed to crank in functions by following curves during the process of solution.[24] This room-sized differential analyzer, pictured above, is what we might say the electro-mechanical forerunner to the laptop. The analyzer was electrically-powered. The positions of gears and shafts represented numbers. Whenever a new problem was to be solved, mechanical linkages had to be disassembled and rebuilt by hand. Gears had to be lubricated, and their ratios adjusted to precise values. This was Shannon's job. It took several days to set up an equation and several more days for the machine to solve it. When finished, the machine would plot out a graph by dragging a pen across a sheet of paper fixed to a draft board.[27]

Thinking about the machine convinced Shannon that electric circuits could compute more efficiently than mechanical linkages, and his credit to genius was to envision an ideal computer in which numbers would be represented by states of electrical circuits—a vision that began to come into fruition when he later, in 1948, saw American electrical engineer William Shockley's newly invented transistor sitting on his desk at Bell Labs, and asked him what it was.[27] The rest is computer history.

Also of interest, during this period, was a complex relay circuit associated with the differential analyzer that controlled its operation and involved over one hundred relays. In studying and servicing this circuit, Shannon became interested in the theory and design of relay and switching circuits. His previous studies of the symbolic logic of Boolean algebra helped him to realize that this was the appropriate mathematics for studying such two-valued systems.

In 1937, at the age of 22, he developed these ideas, initially during his summer stay at Bell Labs, Murray Hill, New Jersey, then back during the school year at MIT, which resulted in his master's thesis, completed that year, wherein he showed how Boolean algebra could be used in the analysis and synthesis of switching and computer circuits.[24] Harvard multiple intelligences theorist Howard Gardner called it 'possibly the most important, and also the most famous, master's thesis of the century.'[25] American science biographer William Poundstone classifies it as 'the most important master's thesis of all time.'[27] Shannon, resultantly, has since come to be known, in modern computer technology times, as the founder of digital communications.[169] Shannon, however, is not, to be absolutely clear, one of the founders of thermodynamics, as some currently believe.[26] In mathematical form:

$$\text{Digital communications} \neq \text{Thermodynamics} \approx \text{Statistical mechanics}$$

The year 1937, in short, was the start of computer language as we now know it. Nearly all of this computer and communication language development occurred at the top secret Bell Labs, shown below, right, which is pictured next to the Institute for Advanced Studies, Princeton, New Jersey, below left, where three years later Neumann would consult Shannon into naming his transmission of information formula by the name entropy:[27]

Institute for Advanced Studies, Princeton, New Jersey; the place where Neumann told Shannon in 1940 to call his function entropy.[2]

Bell Labs, Murray Hill, New Jersey; the place where Shannon, in his classified cryptography report of 1945 uses the word 'entropy' exactly once.[28]

It was Shannon who had the idea that computers should compute using the now-familiar binary digits, 0's and 1's. He described how these 'binary numbers'—or *bits*, as Shannon's associate mathematician John Tukey in 1946 would later come to coiningly call them (or *alternatives*, as Shannon had called them the year prior, i.e. the decision between zero and one is an 'alternative')—could be represented in electric circuits.[170] A wire with an electric impulse represents 1, and a wire without an impulse represents 0. This minimal code may convey words, pictures, audio, video, or any other information.[27]

Unit problem

It should noted, at this point, that a choice or decision between zero and one, or between two symbols, the choices being called *alternatives* (Shannon) or *bits* (Tukey), whether processed in the mind of a telegraph operator or in circuit of a logic gate, is a vastly different conception than that of the unit *joule*—entropy being defined in units of joules per kelvin—which is very complex unit, completely unrelated to what Shannon and Tukey are discussing here. This is what is called the 'unit problem'. In dumbspeak, one will often hear or read queries or comments such as 'well, Shannon entropy and Boltzmann entropy have different UNITS—bits and joules per kelvin, respectively—what is that all about?'

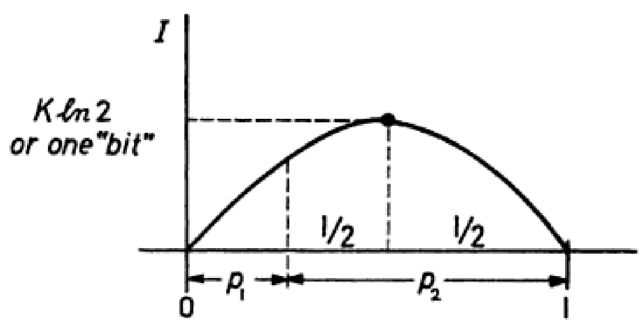
The source of this confusion is a mixture of Neumann, and French-born American Leon Brillouin, who entered the fray in 1949, via his reading of American mathematician Norbert Wiener's cybernetics theories upon which he attempted to develop a negative entropy theory of life, and soon thereafter began to associate bit with joule. American quantum computer scientist Charles Bennett, in his 1988 article 'Notes on the History of Reversible Computation', describes the kT bit folklore as follows:[182]

> "The general folklore belief at this time, descending from Szilard's and Brillouin's analysis, is **expressed in a remark** from a 1949 lecture **by von Neumann**, to the effect that a computer operating at a temperature T must dissipate at least $kT \ln 2$ of energy 'per elementary act of information, that is per elementary decision of a two-way alternative and per elementary transmittal of one unit of information.'"

The Neumann lecture, cited here by Bennett, seems to be one of Neumann's 1949 free energy automaton theory lectures, as found in his collected works book *Theory of Self-Reproducing Automata*.[183] The point to keep wise to here is the 'expressed in a remark by von Neumann' origin of the bit equals k*T ln* 2 units of energy folklore, because, as we will see this is nearly the same as American mathematician Warren Weaver's 1949 footnoted comment that Boltzmann, 'as von Neumann has pointed out', was thinking of entropy in 1894 as missing information. In fact, including these two instances, along with Shannon and Norbert Wiener both crediting discussions with Neumann as the origins of their entropy formulas and namesakes, makes four total instances in which *recourse to authority*, in this case all four citations being recourse to Neumann—in dumbspeak 'Neumann told me so' citations—is used as the foundational basis of the entropy equals information myth.

In any event, in his 1956 *Science and Information Theory*, Brillouin gives the following equation and graph relating information *I* and bits logarithmically in terms of the probability p_i arguments of Shannon's *H* formula:

$$I = -K\,[p_1 \ln p_1 + p_2 \ln p_2].$$



In the same book, Brillouin also attempts to argue that Shannon-based bit information corresponds to negative entropy, or 'negentropy' as he calls it—a neoplasm coining by the way, as Russian scientist Mikhail Bushev cogently points out—based on Austrian physicist Erwin Schrodinger's early 1943 'What is Life?' failed discussion, see his infamous 'Note to Chapter 6', of how life feeds on negative entropy.[225] From here it's not more than one bunny hop away from thinking that this *k* is Boltzmann's constant and that this $k \ln 2$ is the entropy dissipation associated with the bit or binary digit amount of information; though, to note, Brillouin does not use the terms 'erg' or 'joule' in his book, but rather implies the idea.

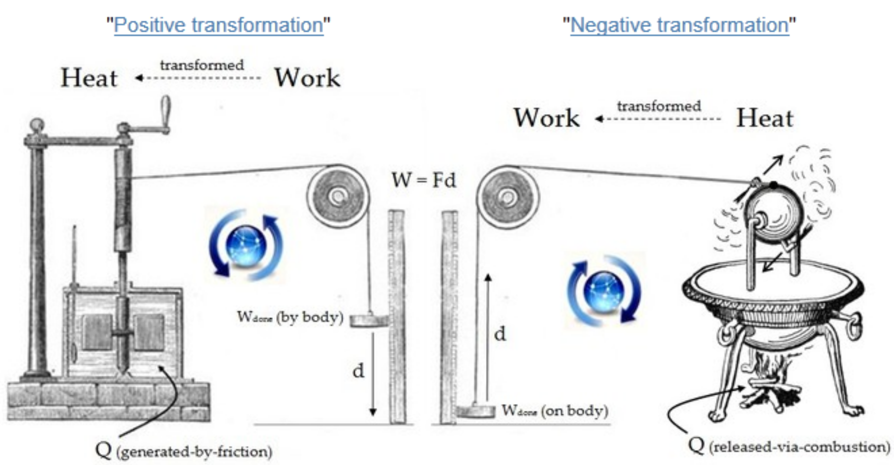
Thus, naturally enough, five years later, in 1961, German-born American physicist Rolf Landauer, in his 'Irreversibility and Heat Generation in the Computing Process' article, proposed that there is an unavoidable cost in entropy whenever one erases information, namely that the entropy of the surroundings must increase by at least $k \ln 2$ per each bit of information erased.[176] In his own words, the 'measurement process requires a dissipation of the order of *kT*.'[171] Landauer's derivation, of course, is a haphazard *form argument*, using the recourse to authority method—he specifically cites 'Brillouin and earlier authors'—in an attempt to argue, in short, that work a single ideal gas molecule does in expanding a piston-and-cylinder to twice its volume is somehow 'miraculously' related to the entropy involved in the storage, removal, and or transfer of the state of a binary digit in a vacuum tube and or quantum mechanical energy well of a transistor. American science historian John Norton, in his recent 2011 article

'Waiting for Landauer, describes Landauer's derivation, for example, as a 'vague plausibility argument'.[172] In short, the Brillouin-Landauer derivation is what's called physical derivation gone awry, or off the connective rails of foundational reality, more to the point.

To be clear, the unit of the joule is based on what is called the *mechanical equivalent of heat*, which is quantified through measured calculation of the ratio with which either work is transformed into heat or conversely heat transformed into work—which is a vast 300-year long intricately complex historical subject in and of itself.[29] The *mechanical equivalent of heat*, by formulaic definition, is the following ratio which is found to be a measured universal constant in nature:

$$J = \frac{W}{Q}$$

where W is an amount of work expended in the production of heat Q, such as in the operation of American-born English Physicist Benjamin Thomson's cannon boring experiments (1798), and or where W is an amount of work produced or obtained from heat Q, such as in the operation of French physicist Denis Papin's steam engine (1690). These two transformation processes, positive and negative, as German physicist Rudolf Clausius defines them, are shown below:



The numerical value of J is independent of the manner in which the heat is produced by work (or work produced by heat). This constant was first enunciated as a formal law of nature by German physicist-physician Robert Mayer in 1842 who stated that the heat produced is proportional to the work done in its production; and conversely, when work is obtained from heat, the heat which disappears is in the same constant ratio to the work obtained.

The exact value of this constant was determined in 1843 by English physicist James Joule who found, through a number of varieties of experiments, that an amount of work W expended in the release of 778-pounds downward in gravitational height by one 1-foot results in an amount of heat generation or work-converted-into-heat quantified by a 1°F temperature increase in 1-pound of water. In unit form, Joules measurement is:

$$J = 778.26 ft \cdot lb$$

With the 20th century introduction of the International System of Units (abbreviated SI from French: Le Système International d'unités), according to which seven *base units*: mass (kg), length (m), time (s), temperature (K), mole (mol), current (A), and light intensity (cd), define all measurements in the universe, the value of J, a derivative unit of the seven base SI units, became defined as 4.186 10^7 ergs per calorie, and assigned a value of 1, after which all forms of energy became expressed in units of 'joules'. With this assignment of J = 1, such as was done in 1924 by English chemist James Partington, the original 19th century mechanical equivalent of heat ratio:

$$W = JQ$$

became reduced to:

$$W = Q$$

where the J is 'assumed' or rather concealed in the proportionality between the two. The take away message here to note is that J the joule is a measured universal constant of nature, derived from the seven SI base units; in the same way that c the speed of light is a measured universal constant of nature. The 'bit' or 'alternative', however, is neither an SI base unit nor a unit derived from the SI base units. That this point is well-understood and agreed upon is hardly the case, as is evidenced by online Q&A debates, such as the 2008 Yahoo Answers thread 'Is Memory (bits and bytes) an SI unit?', started by a United Kingdom graduate school student who asked the question in his statistics class, about which the professor didn't have an answer. The best Yahoo Answers chosen, which is fairly accurate, was:[149]

> "Bits and bytes [8 bits] are artificial constructs, not measurable physical dimensional entities."

Bits and bytes are indeed artificial constructs, not something one finds or measures in a combustion reaction or in a body of steam, whereas, conversely, entropy *is* something one finds and measures relative to the structure of physical bodies in various states of existence.

The main thrust of this physical units / mathematical units confusion muck, trace to Shannon's 1948 seemingly innocuous statement, on Neumann's 1940 advice, that 'the form of H will be recognized as that of entropy of statistical mechanics, the constant K merely amounts to a choice of a unit for measure'.[45]

Correctly, the constant K, is called the Boltzmann's constant and does NOT merely amounts to a choice of a unit for measure, but is one of the four fundamental constants of nature, according to certain recent classifications, the other three being: the velocity of light, Planck's constant, and the gravitational constant.[154] This 'Boltzmann's constant is arbitrary' belief, in information theory, has led to the false ideology, by many throughout the world, that the bit and the joule are the same unit among other blurred ideas concerning the two units, the bit being a mathematical number (0,1) of Boolean algebra, the joule being a measureable physical unit of the SI unit system. American physical economics historian Philip Mirowski comments on this blurred confusion in his usual straight from the shoulder manner:[52]

> "Shannon's theory of information has set in motion one of the most farcical trains of misconceptions and **misunderstandings** in the modern history of the sciences, namely, that 'information' is a palpable thing with sufficient integrity to be measured and parceled out like so many dollops of butterscotch."

To give a farcical train example of where this bit/joule misunderstanding leads to paradoxical results, the following is a 1994 reference, found in the appendix to Russian scientist Mikhail Bushev's *Synergetics: Chaos, Order, and Self-Organization*, to the 1977 work of Russian biophysical thermodynamicist Lev Bluemenfeld, wherein, based on the bit equals kT ln 2 energy units argument, Bluemenfeld calculates that the entropy reduction corresponding to the formation of a human is about 300 calories per degree:[177]

> "L. Bluemenfeld indicated that the human body, composed of approximately 10^{13} cells, situated uniquely in the organism, along with the 10^{25} amino acids in them, contains some 10^{26} bits of information. Consequently, one comes to the conclusion, that the construction of such a complex organism out of the initial disordered system of amino acids corresponds to a reduction of entropy by $\Delta S \approx 300$ cal/deg."

This really is a laugh and a half! It is difficult to say which is funnier, Bluemenfeld's calculation here or the earlier *circa* 1930 rectal temperature/brain temperature calculation of the so-called entropy pulsation of a human by Ukrainian-born Austrian psychologist Siegfried Bernfeld and American physicist Sergei Feitelberg.[178] Both of these examples are physical derivations gone awry.

Correctly, to digress, the formation of a complex organism, such as one single human—technically a person, in the chemical thermodynamic sense, is called a *human molecule*, a 1789 coining of French moral nature philosopher Jean Sales—is the result of an approximate 26-million-year coupled chemical reaction synthesis process—*synthesis* means to form; *analysis* means to take apart—each step in the chemical mechanism corresponding to one generation cycle, reproduction being defined generally as a double displacement reaction, wherein CHNOPS-based genetic material, the C, H, N, O, P, S atoms being elemental material of intelligent motile animation, or pre-genetic material, depending, unites to form a new chemical species.[179] Each step is coupled, one to another, thermodynamically. The entropy change in the formation of, say, a human is thus a summation of the entropy changes for each of these generation reaction mechanism steps, going back 26-million years, the average period of mass extinction. American physical chemist Martin Goldstein, in his 1993 book *The Refrigerator and the Universe*, chapter subsection 'Entropy of a Mouse', buts it like this:[180]

> "To apply thermodynamics to the problem of how life got started, we must ask what net energy and entropy changes would have been if simple chemical substances, present when the earth was young, were converted into living matter [as in the formation of a mouse]. To answer this question [for each process], we must determine the energies and entropies of everything in the initial state and final state."

This is where the 'real' calculation for the entropy of a human lies, not in bit calculations. A quick off the cuff calculation, in the correct *synthesis* perspective, indicates that the measure of the existence state of entropy of a presently synthesized moving about on the surface of the earth human or human molecule involves the following amount of entropy change:

$$S^{\circ} = \left(\frac{1}{300K}\right)\left(\frac{4.18J}{cal}\right)\left(\frac{2000cal}{day}\right)\left(\frac{360day}{yr}\right)\left(\frac{26{,}000{,}000year}{synthesis}\right)(0.50)(0.50) = 10^{12}\,\frac{J}{K}$$

This calculation is based on what's called the Gibbs free energy of formation, 'for a human', method, or 'for a mouse' for that matter, the gist of which is depicted below, as adapted from American physicist Daniel Schroeder's 2000 *Thermal Physics* textbook, his comments shown to the right:[187]

"To create a [human or mouse] out of nothing and place it on the table, the magician need not summon up the entire enthalpy, $H = U + PV$. Some energy, equal to TS, can flow in spontaneously as heat; the magician must provide only the difference, $G = H - TS$, as work."

Historically, the methodology for calculating the free energies of chemical species was worked out in the early 20th century by American physical chemist Gilbert Lewis, as explained in his 1923 *Thermodynamics and the Free Energy of Chemical Substances*.[188]

Related to this, in 1946, American physicist and thermodynamicist Percy Bridgman, during a noted Harvard University 'what is life?' in terms of physics and chemistry debate, commented how he saw a fundamental difficulty in the possibility of applying the free energy of formation methods to any system containing living organisms and specifically that he thought it impossible to calculate the entropy of person:[142]

> "How can we compute or even evaluate the entropy of a living being? In order to compute the entropy of a system, it is necessary to be able to create or to destroy it in a reversible way. We can think of no reversible process by which a living organism can be created or killed: both birth and death are irreversible processes. There is absolutely no way to define the change of entropy that takes place in an organism at the moment of death."

French-born American physicist Leon Brillouin, who was present at the debate, defined this argument as the "paradox of Bridgman" or Bridgman's paradox.[189] Interestingly, in the context of the Bridgman paradox, Lewis, in his 1925 Silliman Lectures 'Anatomy of Science' turned book, gave the following take on the matter:[190]

> "Suppose that this hypothetical experiment could be realized, which seems not unlikely, and suppose we could discover a whole chain of phenomena [evolution timeline], leading by imperceptible gradations form the simplest chemical molecule to the most highly developed organism [human molecule]. Would we then say that my preparation of this volume [*Anatomy of Science*] is only a chemical reaction [extrapolate up approach], or, conversely that a crystal is thinking [extrapolate down approach] about the concepts of science?"

This is all a very excellent Hegelian dialectic juxtaposition of the issue: how do we defining "thinking" if all phenomena is only variations of atomic structures and chemical reactions? Is Lewis himself nothing but a "complex chemical molecule" that has evolved from imperceptible gradations from "simple chemical molecules"? Lewis, in response to these allegations, answers his own questions, as follows:

> "Nothing could be more absurd, and I once more express the hope that in attacking the infallibility of categories I have not seemed to intimate that they are the less to be respected because they are

> not absolute. The interaction between two bodies is treated by methods of mechanics; the interaction of a billion such bodies must be treated by the statistical methods of thermodynamics."

Lewis, does, however, in spite of his present view of the absurdity of thinking along the lines of a *human chemist*—a physical chemist that studies human chemical reactions—leaves the question open to future possibilities:[226]

> "Perhaps our genius for unity will some time produce a science so broad as to include the *behavior* of a group of electrons and the *behavior* of a university faculty, but such a possibility seems now so remote that I for one would hesitate to guess whether this wonderful science would be more like mechanics or like a psychology."

In retrospect, the future 'science' Lewis here speaks of seems to *hmolscience*, a 2010 coined term, which is comprised of the following subfield discipline sciences, the numbers to the right being the number of historically known scholars in each respective field—with some, such as American historian Henry Adams, working in all four fields:[191]

Science	**Definition**	**Definer**	
Human molecule	The atomic definition of a human.	Jean Sales (1789)	121+
Human physics	The study of the forces and movements of human actions.	Adolphe Quetelet (1835)	16+
Human chemistry	The study of the attraction and repulsion of human molecules.	Henry Adams (1875)	68+
Human thermodynamics	The study of systems of human molecules.	C.G. Darwin (1952)	400+

In any event, the above off the cuff calculation of the entropy of a human is made assuming as a ball park estimate that the average total daily energy expenditure of a typical human is 2000 calories, and that this, multiplied by the average mass extinction cycle of 26-million years, gives a reasonable estimate of the free energy of formation for a typical human, with a ½-scaling factor to take into account that daily energy expenditure decreases linearly in a scaling decent down the evolution timeline, and a second ½-scaling factor added, to take into account that entropy tends to be about half of the composition of the free energy change, one of the effects of enthalpy-entropy compensation. American physiologists William McArdle and Frank Katch, to corrobroate, estimate the average energy expenditure for women in the United States is 2000-2100 calories per day and the average for men is 2700-2900 per day.[192] Attempts at entropy calculations of a human, to note, is an historical subject in and of itself, the list of theorizers in this field dating back at least a century: William Fairburn (1914), Bernfeld and Feitelberg (1931), Steven Pierce (1984), Ichiro Aoki (1990s), Attilia Grandpierre (2004), and John Schmitz (2007), to name a few.[227]

The puzzling silliness of the Bluemenfeld result, that the formation of a human involves the entropy reduction of about 300 calories, the amount of energy in typical snack bar, caused Bushev to pen the following retraction note of sorts:[181]

> "On the other hand, the formation of a plain stone of the same mass (e.g. a volcanic rock solidified when lava cools down) corresponds to a considerably bigger reduction in entropy. **There is obviously something wrong** either with the very concept of the relation between symmetry and organization, or with the criterion for the estimation of order in living things—the entropy (or, equivalently, the amount of information)."

There is indeed obviously something wrong! The following calculation by Bluemenfeld, for so-called entropy reduction associated with the formation of a human:

$$\Delta S_{human} \approx 1.3\left(\frac{10^{26} bit}{human}\right)\left(\frac{k_B \ln 2}{bit}\right)$$

which equals about 300 cal/deg, where k_B is $3.3\text{x}10^{-24}$ calories per degree kelvin, is essentially a baseless derivation, namely a double-error filled attempt to force Boolean algebra based computer language mathematics into both genetics, namely the assumption that to code for an amino acid it is necessary to have on average 3-5 bits per amino acid (seems to derive from Brillouin who said: '*information is 4.76 bits per letter*'), and thermodynamics, namely that one bit (binary digit), no matter what the physical structure of the transmission, storage, or manipulation of such, has absolute work energy associated with it, based on hypothetical Maxwell demon calculations, as the work done by a single molecule in expanding a piston to twice its volume. This is what is called the fine print.

In any event, in the Bushev retraction we see the famous rock versus human comparison (or crystal versus human, as Lewis used), such a depicted below, a subject comparison commonly brought up in the hmolsciences, done to get a third party perspective handle on whatever it is one is debating about:[193]

The point to take away here is that if you hear someone discussing Shannon and Boltzmann in the same paragraph, in which they argue that bits and joules are the same thing, can be reformulated to be the same thing, or that the difference between the two of them is irrelevant, or any variations or combinations of these, then you are listening to someone who has been *sokaled* or suckered + Sokal affaired all at once.[30] People who tend to get sokaled are soft science theorists such anthropologist, zoologists, sociologists, and neuropsychologists who—having no formal training in mathematics and the hard physical sciences of chemistry, physics, and thermodynamics—are easily led into these types of snares.

In modern terms, to continue, all of this Shannon-derived computer logic, based on Boolean logic, of 1s and 0s, built into the semi-conductor structure of silicon chips, in the form of AND, OR, and NOT logic gates, that make up the structure of computer memory and computer processing units, and what are called 'truth tables', tables of binary logic, are the tools with which the modern electrical engineer uses to make any and all types of computers. A strong point to keep in mind here, however, is that a coded electric impulse sent down a wire that is translated mathematically into a number: 1 or 0, if no pulse is sent, is not a *unit* of physics, but only a *number* of binary algebra.

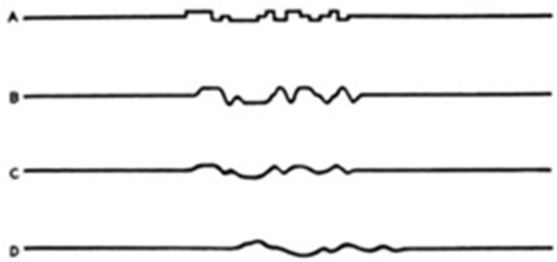
To explain further, via comparison, if we arbitrarily decide to switch to ternary algebra, a base-3 numeral system, and to use ternary logic, logic built on three digits 0, 1, and 2, to build our a new transmission of information theory, according to which the ternary digit analog to the bit becomes the **trit** (**tr**inary dig**it**), where one trit contains $\log_2 3$ (about 1.58496) bits of information, we have thus jumped to a new arbitrary mathematical unit construct. This cannot be done in the case of the joule: the mechanical equivalent of heat is a fixed ratio. Thus the bit, trit, or quatit (**quat**ernary dig**it**), if we were so inclined, are arbitrary numerical constructs, whereas the joule is not an arbitrary construct. In short, great confusion abounds in this conceived to be 'unit issue' when people begin to think that Shannon's *H* measure of information transmission has something to do with the entropy of thermodynamics or with Boltzmann's *H* function. As Schneider comments on this:[31]

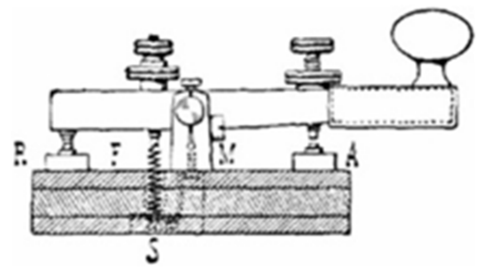
> "The use of the term 'Shannon entropy', although Shannon himself did this, **is a mistake** because it leads to thinking that thermodynamic entropy is the same as the Shannon entropy. Shannon entropy, however, is NOT identical to 'entropy' because they have different units: bits per symbol and joules per kelvin, respective."

Logarithm as the measure of information

In the years 1932 to 1938, in college, Shannon read American electronics researcher Ralph Hartley's 1928 article 'Transmission of Information', presented at the International Congress of Telegraphy and Telephony, wherein it was explained how the 'logarithm', in the form of $x = y \log z$, in Hartley's view, is the best 'practical measure of information', specifically in regard to a telegraph operator sending coded transmissions of 1s (high pulse) and 0s (no pulse) along a cable.[39] Shannon would later describe the reading of Hartley's paper as an 'important influence on my life.'[27] This *is* from where Shannon gleaned the idea of using the logarithm to mathematically formulate signals—NOT by reading the statistical mechanics of Austrian physicist Ludwig Boltzmann, as many now falsely believe and very many falsely popularize as scientific apocrypha.

Hartley, in his article subsection entitled 'The Elimination of Psychological Factors', to explain why the logarithm is best mathematical formula for signal transmission quantification, gives the then-typical situation of a hand-operated submarine telegraph cable system, wherein an oscillographic recorder traces the received message on photosensitive tape, shown below left:





The sending operator, in this example, according to Hartley, has at his or her disposal three positions of a sending key, shown below right, which correspond to three voltage conditions: applied voltages at two polarities and no applied voltage. Hartley then explains the selection process as follows:

> "In making a selection [the operator] decides to direct attention to one of the three voltage conditions or symbols by throwing the key to the position corresponding to that symbol. The disturbance transmitted over the cable is then the result of a series of conscious *selections*. However, a similar sequence of arbitrarily chosen symbols might have been sent by an *automatic mechanism* which controlled the position of the key in accordance with the results of a series of chance operations such as a ball rolling into one of the three pockets."

Hartley then states something that seems to have caught Shannon's eye:

> "[If] a limited number of possible sequences have been assigned meanings common to the [receiver] and the sending operator, [then] in estimating the capacity of the physical system to transmit information we should ignore the question of interpretation, make each selection perfectly arbitrary, and base our result on the possibility of the receiver's distinguishing the result of selecting any one symbol from that of selecting any other. By this means the psychological factors and their variations are eliminated and it becomes possible to set up a definite **quantitative measure of information** based on physical considerations alone."

Here we see the first inklings of the terminologies of Shannon's soon to be *transmission* of information theory or 'information theory' as it quickly came to be called—though Shannon, as he would later reflect, didn't like this term. As Shannon's associate Italian-born American MIT electrical engineering professor Robert Fano commented in a 2001 interview:[32]

> "I didn't like the term information theory. Claude didn't like it either. You see, the term 'information theory' suggests that it is a theory about information—but it's not. It's the *transmission* of information, not information. Lots of people just didn't understand this. I coined the term 'mutual information' to avoid such nonsense."

In this statement it should be plain as day that the theory of the *transmission* of information, which has the mathematical form: 0011010…, being an abstract coding language based on Boolean algebra, or the theory of the transmission of *mutual information*, as Fano describes things, is NOT—in any sense of the matter—the same as the theory of the *transmission* of heat, which has the mathematical form: $\frac{dQ}{T}$, a physical quantity based on Euler-Lagrangian mathematics, in particular what is called the Euler reciprocity relationship.[228] The point to note here, as summarized by Americans thermodynamicist Harold Morowitz (1991) and as paraphrased by environmental economists Thomas Beard and Gabriel Lozada (1999), is that:[146]

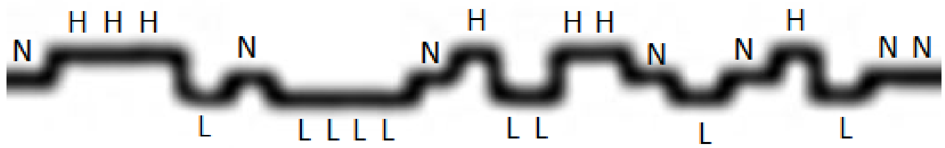
> "[The] 'entropies' in contexts where temperature *T* is absent have NOTHING to do with entropy of thermodynamics and NOTHING to do with the second law of thermodynamics."

If we could all let this point digest, it would certainly be a great help. A step through the sixteen-person Euler genealogy that led to the latter *form*—or 'isomorphism' as discussed—as compared to the three-person Boole-Hartley-Shannon genealogy that led to the former *form* should certainly clarify that the mathematics behind the *transmission* of information have little in common with the mathematics behind the *transmission* of heat.[33] Shannon's 1948 cloudy statement the two equations—his *H* function and Boltzmann's *H* function—have the same *form*, hence they are the same, has caused irreparable damage.

Here again we see further reason for the continued confusion in attempts to correlate thermodynamics and information theory, namely people incorrectly assuming that an equation explaining the *transmission* of mutual information is the same as an equation approximating the entropy of a gas—the state function formulation of the *transmission* of heat—or more specifically the negative of the velocity distribution of a system of molecules of an ideal gas obeying the Boltzmann chaos assumption, which Austrian physicist Ludwig Boltzmann hypothesizes to be representative measure of Clausius entropy, for specifically an ideal gas phase situation—which is a repercussion of the fact that *information theory*, as Fano notes, is an incorrectly understood term.

Examples of this incorrect understating result when one reads terminology blurred notions such as the 'entropy of grammar' (Leo Depuydt, 2007), the '[thermodynamic] entropy of the base composition of *micrococcus lysodeikticus* is 2 bits' (Lila Gatlin, 1972), 'tomorrow we will have learned to understand and express all of physics in the language of information' (John Wheeler, c.1991), 'information theory explains the origin of life' (Yockey, 2005), 'information dominates the energetic process of the physical world and giving rise to life' (Robert Frenay, 2006), 'scientific proof of pandeism under information theory' (Robert Brown, 2009), among other nonsensical statements; namely that people confuse, misuse, and abuse equations and concepts designed to explain *information transmission* to make platformed agenda arguments about *information* in general on any and all sorts of topics.[34] This becomes particular evident when one comes across thermodynamics metaphor blended concepts such as the conservation of information (fictional analogy of *conservation of energy*), information increase (fictional analogy of *entropy increase*), or information tending to a maximum (fictional analogy of the *second law*).[35]

To continue, Hartley, in his article, explains that in his diagram (above), the four lines represent four different recordings of a given transmission, where A shows the sequence of the key positions as they were sent, and B, C, and D are traces made by the recorder when receiving over an artificial cable of progressively increasing length. Figure B shows a signal that can be reconstructed to read the original sequence, whereas C shows that more care is needed to reconstruct the original message, and D show a hopelessly indistinguishable message. Message tracing line A is shown below, labeled with high voltage switch (H), low voltage switch (L), and no voltage (N):



If we defined the no voltage level as a space, the above coded message, in binary, with H = 1 and L = 0, would read as such: 1110 0000 10011 0 10, whereby, for instance, in modified Boolean-type Morse code, the first number sequence 1110 could be mutually-defined to mean represent the word 'hello', a type of binary language. Hence, in this scenario, we are transforming binary algebra into information—but not, however, transforming heat into work or work into heat.

To put this information transmission into logarithmic formulation, Hartley explains that at each point in the reading of the recorded tape of the transmitted signal, the reader must select one of three possible symbols (H, N, or L), a number which Hartley assigns to the symbol *s*. He then explains that if the telegraphy reader makes two successive selections, symbolized by *n* (the symbol 'n' possibly for *number* of selections), he or she will have 3^2, or 9, different permutations or symbol sequences. In the binary case, two key positions (or no current = space), this would be 2^2, or 4. This system can then be extended to that in which, instead of three different current or voltage levels to select from, the sender has *s* different current values to be applied to the line and to be distinguished from each other at the receiving end of the line. The number of distinguishable sequences, per number of symbols (or voltage levels) available at each selection *s*, given a certain *n* number of selections is:

$$s^n = \text{number of voltage levels}^{\text{number of selections}}$$

Subsequently, the measure of the amount of information transmitted will increase exponentially with the number of selections. The solving and quantification of 'exponential' functions tend to be facilitated by using logarithms. This is one of the reasons why both Boltzmann *H* function and the Shannon *H* function have use logarithms: both the 'amount of information' and the number of 'microscopic states' available to molecular velocities will increase exponentially with the number of selections and with the amount of heat added to the body, respectively. This commonality, however, is inconsequently—a repercussion of the mathematics involved.

Hartley, to continue, then states that we may *arbitrarily* put the amount of information transmitted in a telegraph message as being proportional to the number of selections *n* as follows:

$$H = Kn$$

where *H* is Hartley's symbol for *amount of information* and *K* is a constant that depends on the number *s* of symbols available at each selection. Then, through a few derivation steps, he arrives at the following logarithmic expression for information:

$$H = n \log s$$

representing the 'amount of information' associated with *n* selections of a system capable of sending *s* number of signal levels. Hartley then comments in summary:

> 'What we have done is to take as our **practical measure of information** the *logarithm* of the number of possible symbol sequences.'

This is the starting point for what would later become Shannon's *H* function (aka Shannon entropy). Shannon, in his 1982 oral history interview with American communications engineer Robert Price, would later reflectively comment on this Hartley paper:[36]

> "I started with Hartley's paper and worked at least two or three years on the problem of information and communications. That would be around 1943 or 1944; and then I started thinking about cryptography and secrecy systems. There was a close connection; they are very similar things, in one case trying to conceal information, and in the other case trying to transmit it."

These, of course, were war time years; seventy-four percent of Bell Lab's 2,700 engineering staff, for example, were assigned to military projects from 1942 to 1945; hence it is no surprise that Shannon, being part of Bell Lab's staff, was thinking about cryptography during these years. The first published use of the term 'entropy' by Shannon is found used one time in a then-classified September 1st, 1945 confidential report entitled 'A Mathematical theory of Cryptography'.[37] The original classified version seems to be difficult to track down. To get a feel for what he might of said about entropy in his classified 1946 report, in readily available declassified slightly expanded 1949 version, entitled 'Communication Theory of Secrecy Systems', wherein he cites back to his 1948 'A Mathematical Theory of Communication', Shannon uses the term entropy nine times, in the first of which he states:[38]

> "The second part of the paper deals with the problem of 'theoretical secrecy'. How secure is a system against cryptanalysis when the enemy has unlimited time and manpower available for the analysis of intercepted cryptograms? The problem is closely related to questions of communication in the presence of noise, and the concepts of **entropy** and equivocation developed for the communication problem find a direct application in this part of cryptography."

A reading of this 60-page report should thoroughly convince the reader that use of the term 'entropy' here in regards to the analysis of intercepted cryptograms, the 16th century Vigenere cipher method, shown below, being one example from the report:

Message	*S E N D S U P P L I E S* ···
Key	*C O M E T S E N D S U P* ···
Cryptogram	*U S Z H L M T C O A Y H* ···

as was invented by French cryptographer Blaise de Vigenère and used for data encryption—in which the original plaintext structure is somewhat concealed in the ciphertext by using several different monoalphabetic substitution ciphers rather than just one; the code key specifies which particular substitution is to be employed for encrypting each plaintext symbol—has absolutely NO relation whatsoever to the 19th century physics concept of 'entropy' derived by German physicist Rudolf Clausius

(1865) or the modified *H* theorem version of 'entropy' developed for ideal gas theory in by Austrian physicist Ludwig Boltzmann (1872).

This, in any event, is from where Shannon information theoretic entropy originated: from study of Hartley's 1928 article 'Transmission of Information', originally presented at the International Congress of Telegraphy and Telephony, lake Como, Italy, September, 1927.[39] This is the derivation root of Shannon's *H* function. There is no connection at all here to thermodynamics or statistical mechanics. The apocryphal connections that one often tends to read about are but later conjured up adumbrations, done for who knows what reasons?

Keeping to the focus of the present article, one notes at this point, that owing to Shannon's misfortunate 1945 namesake adoption of a term from a completely unrelated field, that we are now forced into to the *mouthful* use now of three extra clarifying terms—'Shannon, information, and theoretic'—to distinguish exactly what we are talking about here, namely information theory or thermodynamics, among other term clarifiers, such as outlined below:

Information theory	≠	Thermodynamics
Hartley entropy S_H, the above *H* log function derivation by Hartley, Shannon discrete entropy $S_{S,d}$, messages are discrete and sent by the source one after the other, such that $m = \{m_1, \ldots, m_n\}$ is the complete set of messages, in the sense that the source cannot send messages other than the m_i (high or low pulse), conditional Shannon entropy $S_{S,d}$, which measures the average information received from a message m_k, given that a message s_j has been received before, continuous Shannon entropy $S_{S,c}$, the measure generalized to the continuous case using an integral rather than a summation, Renyi entropy S_R, a generalization of Shannon entropy, requiring that it satisfies all the axioms of Shannon entropy, except for branching, Renyi entropy of order q $S_{R,q}$, being a special case of the latter.		Thermodynamic entropy S_{TD}, the original entropy as quantified by the Clausius inequality (the term 'thermodynamic entropy', to be clear, is a neoplasm, not used by thermodynamicists), statistical mechanical entropy S_{SM}, of which there are generally two main varieties: the Boltzmann entropy and the Gibbs entropy, each of which have sub-varieties, namely the fine-grained Boltzmann entropy $S_{B,f}$, also called *continuous Boltzmann entropy*, the 1872 version of entropy derived by Boltzmann, namely Clausius entropy argued to be proportional to the negative of Boltzmann's *H* theorem for an ideal gas system, the coarse grained Boltzmann entropy $S_{B,w}$, also called *combinatorial entropy*, the famous $S = k \log W$, version of entropy engraved on Boltzmann' tombstone, where 'w' denotes partition, from the German *Wahrscheinlichkeit* (var-SHINE-leash-kite), meaning probability, often referred to as multiplicity (in English), the 1877 upgrade version derived by Boltzmann, in response to criticism of his 1872 version, the one that uses elementary combinatorial considerations to shown that *W* is equal to the number of microscopic states of the particles of the system, states here conceived as hypothetical rectangular cells with respect to position and momentum coordinates of the each respective particle, the Boltzmann entropy of a macrostate $S_{B,m}$, a special case of the latter, and the sub-varieties of the latter, namely the fine-grained Gibbs entropy $S_{G,f}$, also known as *ensemble entropy*, which differs from Boltzmann slightly by using what is called an *ensemble*—an uncountable infinite collection of independent systems that are all governed by the same equations, but whose state at a time *t* differ, and the coarse-grained Gibbs entropy $S_{G,w}$, where in this case 'w' stands for partition.

This terse synopsis of the various so-called 'entropies', informational verses thermodynamical, comes from the chapter 'Entropy: a Guide for the Perplexed', written by English theoretical physicist and philosopher Roman Frigg and English logic philosopher Charlotte Werndl, as found in the 2011 multi-author book *Probabilities in Physics*.[40] In a point of departure from their types of entropies summary, wherein they attempt, here and there, to make connections, such as between Gibbs entropy and Shannon entropy, e.g. by citing American engineer Mark Jaynes' so-called maximum-entropy principle theories, which as American engineer Myron Tribus commented about in 1998 was a 'completed failure', we herein strongly state that Gibbs entropy and Shannon entropy are *completely unrelated*—there is no 'connection' between the two, as many, over the years, have grasped for like a person grasping a straw lost in the desert seeing a water mirage.

In summary, the proliferation of the above terminology-blurred overlap of two completely unrelated fields is a long-overdue clarion call for terminology reform in the sciences and engineering fields—in short: the name Shannon entropy needs to be changed. Suggestions for this move will be discussed at the end of this article.

If, keeping to the focus of the present article, in a given communication system, there were two voltage levels available for sending messages, high or low, the Hartley information equation, or Hartley entropy as we have incorrectly referred to it above, would become:

$$H = n \log 2$$

Moreover, if we make only one selection *n* then the equation becomes:

$$H = \log 2$$

In words, referring to the Baudot coding system, as developed in 1870 by French telegraph engineer Emile Baudot, Hartley explains:

> "If we put *n* equal to unity, we see that the information associated with a single selection is the logarithm of the number of symbols available; for example, in the Baudot system the number *s* of prime symbols or current values is 2 and the information content of one selection is log 2."

To clarify, in regards to the phrase 'information content of one selection', explicitly Hartley is speaking here of a telegraph operator or a machine reading a single high (H) or a low (L) voltage tracing off of the photosensitive tape—and that this message fragment reading has an information content value of:

$$\log_{10} 2$$

or

$$0.30102 \ldots (no\ units)$$

There are no SI units here, this is just a number.

Logarithm in thermodynamics

The reason for going into such detail here is that two years later, in 1929, Hungarian-born American physicist Leo Szilard, as mentioned, formerly-published his earlier 1922 demon mental entropy article, in the German periodical *Zeitschrift fir Physik* (*Journal of Physics*), where he argued that the following equation represents the approximate entropy dissipation that occurs in the memory processing of an 'exactly informed' Maxwell's demon:[41]

$$S = k \log 2$$

which has the value of:

$$\left(1.346 \times 10^{-16} \frac{erg}{deg}\right) \log_e 2$$

or

$$9.33 \times 10^{-17} \frac{erg}{deg}$$

using the then-standard Planck-usage centimeter-gram-second unit system for Boltzmann's constant k, the value of S being the entropy dissipation occurring during the demon's mental reading of a parameter y, the position coordinate for one molecule inside of a bi-compartment piston and cylinder, that is correlated to a fluctuation parameter x of the system.

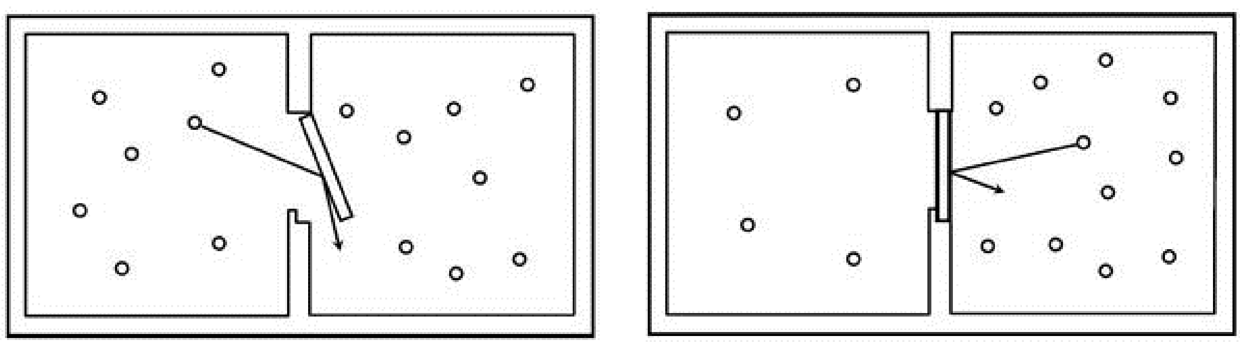
Szilard, again, was a close friend of John Neumann, who in turn, soon came to be aware of Szilard's 1922 derivation, which he assimilated into his own similarly-themed 1932 quantum entropy derivation, would later separately advise both Claude Shannon, in 1940, and Norbert Wiener, in the years *circa* 1937 to 1947, to call their respective information transmission formulas by the name 'entropy' because of the similarity of the mathematical *form* the two derivations, Hartley and Szilard, respectively. The following 2010 quote from the film *Inception* seems well-apt here:

> "About inception. An idea is like a virus, resilient, highly contagious. The smallest seed of an idea can grow. It can grow to define or destroy you."

Neumann simultaneously planted seeds in the minds of both Shannon and Wiener. This is the rotten root of the alleged notion that information theory is 'thermodynamical', an assertion which is NOT true, in any sense of the matter. Neumann, in regards to the unit problem, as mentioned, also played a role in the convoluted idea that the transmission and or storage of a bit of information has an entropy generation of $k \ln 2$. Neumann, as we see, for whatever reason, likes stirring the witch's brew—for Neumann, however, is concern was not with communication theory, but with the nature of the newly-proposed 'uncertainty' problem of quantum mechanics, namely that to 'measure' a molecular variable, one has to shine light on it, the light, in turn, subtly perturbs the measured variable, thus precluding precise measurement—this is what Neumann was after in his comments about entropy and information *measurement*. Somehow, this notion got lost in translation in the minds of Shannon and Wiener in their respective consultations with Neumann about entropy?

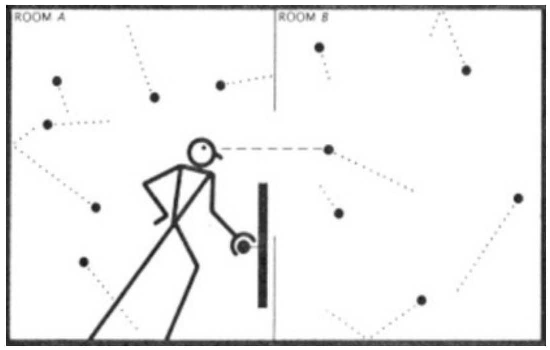
Shannon specifically told American engineer Myron Tribus in 1961 that Neumann was the one who told him to call his new formula (H function) by the name 'entropy' and, likewise, Wiener specifically states, via footnote 3.1 in his 1948 *Cybernetics*, that he 'makes use of a personal communication with J. von Neumann' in regards to his entropy namesake usage and formula for the measure of the *amount of information*, contained in a rapidly changing sequence of voltages in a telephone line or a television circuit or a piece of radar apparatus. These two parallel seemingly independent usages of the Neumann-fueled suggestion that entropy equals information—though, to note, Shannon used a plus '+' sign in his equation, whereas Wiener used a negative '–' sign, and they both were a little confused about this mutual discrepancy, though, following conversation on this, eventually brushing it off in the end as a trivial matter—has resulted in what has become a grand scale deeply embedded urban myth in modern science: namely the myth that information theory is based on thermodynamics—or in some nearly upside down insane asylum cases that thermodynamics is based on information theory. We are thus forced here to play the role of myth buster.

To go into more detail, in regards to the origin of the Szilard derivation, in 1912 Austrian-born Polish statistical physicist Marian Smoluchowski, in his lecture 'Experimentally Demonstrable Molecular Phenomena, which Contradict Standard Thermodynamics', discussed 'fluctuations' or special states of matter where spontaneous deviations from the average value of some property (e.g. pressure or density) suddenly become very large, such as occurs in phase transformations, and on this platform asked if it could be possible to use these pressure fluctuations to push a one-way door, such that a high pressure would open the trapdoor, low pressure would keep the door closed, and as such the door would act like an automated Maxwell demon—similar to Maxwell's *circa* 1876 'Concerning Demons' letter, wherein he comments how the demon can be reduced to a valve:[147]

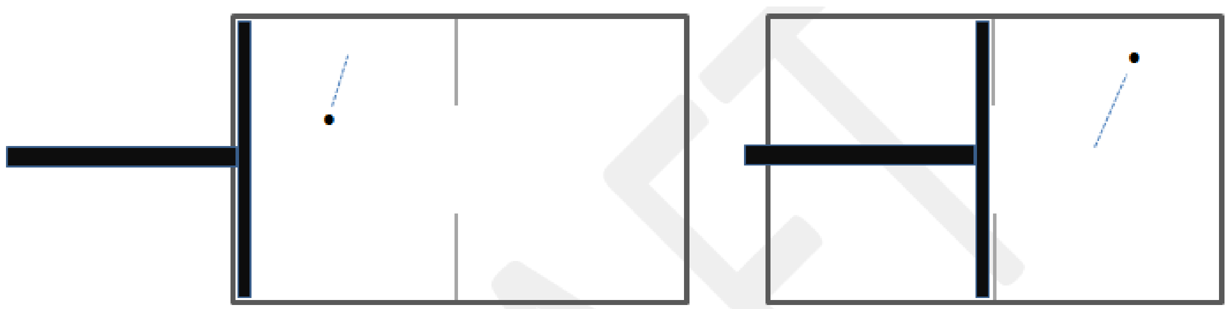


Thus, in principle, if the right sized trap door, being in proportionate size to the fluctuation magnitude, were used, particles could be worked to go from the right to left, and create a temperature difference without work, in violation of the second law, thus creating perpetual motion of the second kind. Smoluchowski, however, dismissed the idea that an actual violation of the second law could occur—except, as he weakly stated near the end of this lecture, in the rare case if one were willing to wait long enough—pointing out that if the door were too weak, it would be subject to thermal motion and begin to vibrate randomly, negating the violation ability possibility.

In 1922, intrigued by Smoluchowski's argument, Szilard wrote his 'On the Decrease of Entropy in a Thermodynamic System by the Intervention of Intelligent Beings'—which, to be clear, has absolutely NOTHING to do with Hartley or his formula for the amount of information associated with *n* selections of a Baudot coding system—in which he upgraded Smoluchowski's hypothetical second law governed trap-door to the scenario where a physical demon exists whose *mental operations* are governed by the second law. In this sense, Szilard hypothesized that energy dissipated in the ‘act’ of the memory processing of the demon during the reading of one state parameter gauged to the *molecular fluctuations* inside a bi-compartment divided vessel, containing one molecule in an ideal gas state, as shown below, moving about between the compartments A and B:



has, as mentioned, a hypothetical entropy production of *k* log 2 associated with this hypothetical demon mental energy dissipation, which is an entropy production estimate based on the easily derivable value of the work required to slowly push a piston containing one single molecule, in the ideal gas state, from the extreme right of the cylinder to the middle wall, as shown below:



To do a quick derivation, of this so-called demon memory entropy work, the first condition we stipulate is that the process is done very slowly, the model of the infinitely slow rate, idealizing the view that the temperature of the gas never differs from that of the surroundings. The process is thus defined as being an isothermal process. A second assumption is that the compression is done ‘infinitely slow’ means that model the process as being reversible, and thus use the equals sign ‘=’ instead of the Clausius inequality ‘< ’ in our expression for the first law equation for this process. Therefore, according to Joule's second law, which states that the internal energy *U* of an ideal gas is solely a function of temperature *T*, we have:

$$U = f(T)$$

the internal energy change for this compression process will be zero and, thus, according to the first law of thermodynamics :

$$dU = dQ - dW$$

the heat change dQ occurring in the process will be converted completely into the work dW of expansion:

$$dQ = dW$$

To then calculate this compression work W we use French physicist Emile Clapeyron's 1834 expression for the pressure-volume work:

$$W = \int_{v1}^{v2} P dv$$

We then use the statistical ideal gas law, as was introduced in the 1900 work of German physicist Max Planck, shown below:

$$PV = NkT$$

where N is the actual number of molecules in the system, in our single molecule case $N = 1$, and k is the Boltzmann constant. With substitution, this gives the work integral function:

$$W = NkT \int_{v1}^{v2} \frac{1}{V} dv$$

The above integral has the form of what is called a 'definite integral', one with upper and lower limits, which integrates according to the following rule:

$$\int_{x1}^{x2} \frac{1}{x} dx = \ln |x_2| - \ln |x_1|$$

Here we see the 'logarithm' enter the picture. The reason why the integral of $1/x$ equal to the natural logarithm of x, is best explained graphically, but is a digression we will not go into at this point.[42] The point to keep in mind here, in regards the present article, is that the logarithm is entering the derivation here in a different manner than the way the logarithm entered the picture in the Hartley derivation. This is one of the fine print details that thinkers who believe that Shannon entropy equals Boltzmann entropy fail to take note of, and hence is one of the reasons behind French mathematician Benoit Mandelbrot' famous 1961 comment that: 'Everyone knows that Shannon's derivation is in error', in regards to the purported notion that his H function has a thermodynamical basis.[43]

Also, to note, in regards to confusion in comparing the 'types' of logarithms used in 1922 Szilard derivation as well as the 1930 Szilard-based re-derivation done by American physical chemist Gilbert Lewis, as discussed below, the so-called *common logarithm*, which is what Hartley used, have the form:

$$\log_{10} y$$

which becomes what is called the *natural logarithm* when instead of base '10' one uses base 'e', which is what Szilard used. In other words, to clarify, if the base is e, where e = 2.71828 ..., the logarithms are called either 'natural logarithms' or Napierian logarithms, named after Scottish mathematician John Napier, the inventor of logarithms, which has the form:

$$\log_e y$$

or

$$\ln y$$

which are taken to be equivalent notational formats; hence Szilard and Lewis, discussed below, are using the same base e logarithms. Shannon logarithms, however, to absolutely clear, are base 2 common logarithms, and Hartley logarithms are base 10, another often overlooked factor when people naively assume information entropies and thermodynamic entropies are the same, which is not the case. The natural logarithm has widespread in pure mathematics, especially calculus. The common logarithm has common usage in many applications in science and engineering. To continue, using the above rule for the definite integral of $\frac{1}{x}$, we have:

$$W = NkT(\ln v_2 - \ln v_1)$$

This can be reduced, using the rule that the logarithm of a ratio is the difference of the two logarithms:

$$\ln \frac{x}{y} = \ln x - \ln y$$

to the following form:

$$W = NkT \ln \frac{v_2}{v_1}$$

With substitution of this into the reduced first law, above, we have:

$$\Delta Q = NkT \ln \frac{v_2}{v_1}$$

Then, bringing the temperature over, we have:

$$\frac{\Delta Q}{T} = Nk \ln \frac{v_2}{v_1}$$

which by definition (Clausius, 1865) is thus the entropy change of the body of gas during the expansion:

$$\Delta S = Nk \ln \frac{v_2}{v_1}$$

If the volume of state two is twice that of the volume of state one, i.e. $V_2 = 2V_1$, which is the case in our situation, then this equations reduced to the following:

$$\Delta S = Nk \ln 2$$

and since, as mentioned, we are dealing with a system containing one molecule, i.e. N=1, our equation reduces, with the removal of the delta symbol, referring to the final state entropy, to the following:

$$S = k \ln 2$$

which is what Lewis derived (below) and in which Lewis says is the *entropy decrease* when we 'know which is the flask in which the molecule is trapped' or conversely, as he rephrases it, 'gain in entropy always means *loss of information*, and nothing more.'

Here to point out another area of confusion, the number '2' here is a trick result arrived at by setting the volume of state two equal to twice the volume of state one:

$$V_2 = 2V_1$$

which is complete different from the way in which the number '2' entered the picture in the Hartley derivation, which as to do with the specific case in which there are two symbols in a message to choose from. People naïve to these details will think, in dumbspeak, 'well, there's a 2 in both formulas, they must thus be explaining the same thing'. This, of course, is a nearly childlike statement, but one that many have invariably fallen victim to.

To be very clear, at this point, being that information theorizers continuously tend to cite this 'information loss' comment, outlined below, by Lewis as a supposed proof that information and entropy are the same thing, which is not the case, here, we are talking about a hypothetical demon losing track of which side of a trapdoor separated bicompartment vessel a molecule is in, NOT *loss* of coding of *digital information* or uncertainty in a telegraph transmission or cryptography semantics. This is a prime example of something getting lost in translation.

That piston and cylinder work is the same as demon mental entropy production is a conjectural discussion in and of itself, outside of the focus of the present article. The reason why the Szilard article is discussed here is that in the year to follow, in 1930, American physical chemist Gilbert Lewis in his 'The Symmetry of Time in Physics', an address given on the occasion of the presentation of the gold medal of the Society of Arts and Sciences, New York, April 17, built on Szilard's paper, albeit giving a cleaner derivation and presentation, stating that 'in dealing with the individual molecules we are perhaps arrogating to ourselves the privileges of Maxwell's demon; but in recent years, if I may say so without offense, physicists have become demons', this being a jab at Szilard, during the course of which Lewis steps through an argument, in which three molecules, A, B, and C, are moving about in the above type of bi-compartment piston-operational vessel arrangement, albeit one with semi-permeable molecular pistons, i.e. pistons selectively permeable to specific molecules, showing that when any *known* distribution—say A, B, and C—on one side—goes over to an unknown distribution—say by opening the shutter—the increase in entropy of the irreversible process is, 3 k ln 2, where here he is using a *natural logarithm*, and that in the simplest case, when we have one molecule which must be in one of the two sides, that the entropy becomes less by:

$$S = k \ln 2$$

if we know, i.e. have positional *information*, in which container side the molecule is in—and in his famously re-quoted, by information theorists, concluding remark states:[44]

> "The gain in entropy always means loss of information."

This, of course, has absolutely NOTHING to do with Hartley's 1927 information equation:

$$H = n \log 2$$

Equations that have the same 'form' but different functions, as used in different fields, as mentioned, are what are called *mathematical isomorphisms*.[20] This is another area of common confusion: people thinking that just because two equations are isomorphic that they are the same.

In any event, into the next decade, in 1948, on the strange humor 1940 advice of Neumann, all of this became convoluted together when Shannon borrowed the name 'entropy' for his new modified version of the Hartley information equation:[45]

$$H = -K \sum_{i=1}^{n} p_i \log p_i$$

where *K* is constant, which, according to Shannon, depends on the choice of a unit to measure, and *pi* are the probabilities, a number between zero and one, of occurrence of a set *i* of possible events, of a Markoff type (memoryless) information source, and where *H* is measured in units of bits per symbol.[83] To clarify, this equation has absolutely NOTHING to do with thermodynamics. Nor does this *H* function have anything to do with the *H* function of statistical mechanics, which is an entropy approximation formula, developed by Austrian physicist Ludwig Boltzmann, for an ideal gas.

Symbol overlap

At this point we see a great deal of overlap. Firstly, in symbols, *H* being used in both information theory and statistical mechanics. Secondly, in language, both Lewis (1930) and Shannon (1948), using the terms 'information' and 'entropy' together in sentences. This is one of the main hotspots for confusion. As Hartley warns: 'as commonly used, *information* is a very elastic term, and it necessary to set up a more specific meaning [for each] applied discussion.' Thirdly, we see equation similarity, not only of the mathematical isomorphism variety, but also in the similar usage of the number '2'. Fourthly, we see both Hartley and Lewis speaking about the product of a constant (*n* or *k*, respectively) and the logarithm of 2 being associated with some minimal amount of *information content* or *knowledge*, respectively. Blended together, all of this perceptual overlap creates a false allusion of commonality and hence subject uniformity, which is NOT the case.

In regards to symbol choice, to go into more detail, it is obvious—Hartley having been an 'important influence' in Shannon's existence, as he later commented—that Shannon used the symbol 'H' based on Hartley's earlier usage of the symbol 'H' as the measure of information. Italian information philosopher

Luciano Floridi (2009), for example, comments: 'Shannon used the letter *H* because of Hartley's previous work'.[46] Likewise, American sociologist Kenneth Bailey (1994) states the 'symbol *H* is named after Hartley.'[47] Conversely, to cite a confusion resulting incorrect view, American author James Gleick (2011) states that Shannon 'denoted his *H* after the Boltzmann *H*-theorem'.[48] This latter erroneous supposition is the result of Shannon's 1948 science-ruining statement that:

> "The form of [my new] *H* [function] will be recognized as that of [Boltzmann] entropy defined in statistical mechanics."

and his nearly rule-bending argument that because they have the same 'form', he will also call his new formula by the name entropy. To clarify, in regards to symbol etymology, the letter 'H' of Boltzmann's *H* function, also known as *Eta's theorem*, is from the Greek capital letter Eta, shown below, and is often incorrectly assumed to be from the Latin letter *H*, simply because the two look the same, particularly in the German-to-English rendering:

Hη

The term 'H-theorem' was said to have been an English mistranslation of Boltzmann's term 'minimum theorem', made by English mathematical physicist Samuel Burbury between 1875 and 1894, in the sense of Boltzmann's 'heat theorem', meaning that he mis-interpreted capital eta to be an 'H' as in heat. In any event, in his 1899 book *A Treatise on the Kinetic Theory of Gases,* devoted to an explication of Boltzmann's 1872 work, Burbury states that the *H* theorem is known as 'Boltzmann's minimum theorem' and that *H* is called 'Boltzmann's minimum function or, as it is sometimes, called the entropy function.'[49]

The reason for the above puzzling statement, by Shannon, about bring statistical mechanics into the discussion stems from Shannon's semi-comical discussion with American mathematician and chemical engineer John Neumann, eight years earlier, as discussed further below.

The conversation

To continue with our naming etymology, prior to publishing the above formula, in a February 16th, 1939, letter to American analog computer engineer Vannevar Bush, the eponym of the differential analyzer, that Shannon worked on some years earlier at MIT, Shannon, as mentioned, commented:[48]

> "On and off, I have been working on an analysis of some of the fundamental properties of general systems for the *transmission* of **intelligence**, including telephony, radio, television, telegraphy, etc."

This letter is said to mark the start of information theory.[27]

The following year, in 1940, the finalized namesake for Shannon's *H* formula for the *transmission* of **intelligence**—including telephony, radio, television, telegraphy, etc.—occurred in famous or infamous, depending, retold many-times-over conversation—depicted humorously below—wherein Neumann suggested puzzlingly to Shannon that he use neither of the names: information or uncertainty, but rather jokingly use the name 'entropy' of thermodynamics, because: (a) the statistical mechanics version of the entropy equations have the same mathematical isomorphism and (b) nobody really knows what entropy really is so he will have the advantage in winning any arguments that might erupt.[2]

A 2010 parody of the **Neumann-Shannon anecdote**.[50]

In part (a), of this spurious suggestion, Neumann is, of course, referring, invariably to his Hungarian-born American friend Leo Szilard's 1922 logarithm formulation of demon mental entropy dissipation and to his own 1932 logarithmic formulation of quantum entropy; part (b), however, seems to be a reference to personal experience, namely his own *circa* 1930s debates over the thermodynamic merits of his quantum entropy formulation (or possibly debates of Szilard's entropy), the thermodynamic validity of which, as mentioned, is still being debated presently.[175]

In any event, Scientists have long puzzled as to why Neumann made this out-of-the-blue unwise naming suggestion? Possibly he was unconsciously trying to promote his own theory? American chemist Jeffrey Wicken comments on this, for instance:[8]

> "There is **no need** in information theory to enter the 'entropy means lack of information' arena, or even to talk about entropy."

The above mocking cartoon, to note, is a parody of the infamous 1940 Neumann-Shannon name suggestion conversation, from Israeli physical chemist Arieh Ben-Naim's 2010 chapter section 'Snack: Who's Your Daddy?', in which he retells the story such that Shannon has a new baby and he and his wife are deciding on what name to pick: 'information' or 'uncertainty'? Neumann suggests they name their son after Rudolf Clausius' son's name 'entropy', which Shannon decides to do—only to find out, in the years to follow, that people continually confuse his son with Clausius' son and also misuse and abuse the name; after which, it is suggested to Shannon that he change is son's name from Entropy to Smomi, a short acronym for 'Shannon's Measure Of Missing Information.'[50] This is basically what has been going in the last seven decades: people continually confuse his Shannon's son [entropy] with Clausius' son [entropy] and also misuse and abuse the name. As English science historians Peter Coveney and Roger Highfield put it:[51]

> "The two—information theoretic ideas and thermodynamic entropy—have been **repeatedly confused** since the time of von Neumann."

The Neumann-Shannon anecdote has been told and retold so many times that it has classified by some as urban legend—American physical economics historian Philip Mirowski (2002), for instance, describes it as a 'widely circulated story', whereas some, especially those promoting information + thermodynamics connections, are in denial that the story ever took place at all.[52] French theoretical physicist Annick Lesne, for instance, in her 2011 article 'Shannon Entropy: a Rigorous Mathematical Notion at the Crossroads between Probability, Information Theory, Dynamic Systems and Statistical Physics', describes the Neumann-Shannon anecdote as scientific 'folklore'.[53] In 2011, to exemplify further, Danish mathematician and information theorist Peter Harremoes, the then at the time editor-in-chief of the online *Entropy* journal—a forum launched in 1999 to investigate whether or not there is any correlation between Shannon information-theoretic entropy and thermodynamic entropy—in email communication with the author, commented:[54]

> "Regarding the story about the conversation between von Neumann I am not sure that it is historically correct. Shannon was educated as an engineer and seems to have known the formulas for entropy before he met von Neumann."

These types of denialism mindsets are common among editors, such as voiced in the Wikipedia (2005-2010) and Hmolpedia (2008-present) discussion pages, as the author has frequently noticed.[55] The author, however, who went through the same electrical engineering program, at the University of Michigan, as did Shannon (1932-1936), is well-tuned to what so-called *entropy formulas* the typical electrical engineer learns, and in this perspective will herein attempt to: (a) dispel the Shannon derived the namesake entropy himself myth, (b) derail what is known as the *Shannon bandwagon*, that many are taken for a ride on, and lastly (c) end with an historical timeline of renaming initiatives, inclusive of recent discussion on the matter with some of the historical players in the information entropy field, wherein a formal proposal will be made, as mentioned, to officially change the name of Shannon's *H* formula, throughout the scientific community, from *entropy* to *bitropy*, short for '**bit**-tropy' (binary digit entropy) and or '**bi**-tropy' (two-tropy), depending on one's etymological preference, the latter interpretation meaning *alternative*s, as in a choice between 0 and 1, the name 'alternatives' being original 1945 name that Shannon was using for what in 1946 were coiningly referred to, during a Bell Labs lunch conversation, as ***bits***—John Tukey's shorthand term for **bi***nary digi***ts** (0,1)—to thus remedy, once and for all, what has been a gaping and prolonged mental wound in science.

In short, the story of the Shannon-Neumann name suggestion is historically correct, according to both the published word of American thermodynamics engineer Myron Tribus, who got the story straight from the horse's mouth in person, and according to Shannon's 1982 interview with American communications engineer Robert Price, wherein he commented 'somebody told me'. Specifically, the name suggestion incident became public knowledge when, in April of 1961, Tribus—who had been vexed about the *alleged* connection between Clausius entropy and Shannon entropy ever since he was asked this question during his 1948 UCLA doctorial examination—was invited to give a seminar at MIT on a new way to derive thermodynamics based on information theory. The audience, according to Tribus, was a critical audience, comprised of students of American mechanical engineer Joseph Keenan, founder of the MIT school of thermodynamics, who 'tried to rip it apart', and also that French mathematician Benoit Mandelbrot, as mentioned, was in the audience and quickly attacked the maximum entropy interpretation, saying: 'everyone knows that Shannon's derivation is in error.'

It also happened to be the case that Shannon was in residence at MIT that week, so naturally enough Tribus went to see him. During their discussion, Shannon, according to Tribus, 'was immediately able to dispel Mandelbrot's criticism, but went on to lecture me on his misgivings about using his definition of entropy for applications beyond communication channels.'[43] Indeed: this article, we might say, is an expanded 21st century lecture to everyone in science on the misgivings of using Shannon's definition of entropy beyond communication channels. During this meeting, Tribus queried Shannon as to his reason for choosing to call his information function by the name 'entropy', the details of which were first made public in Tribus' 1963 article 'Information Theory and Thermodynamics', followed by many articles, symposiums, chapters, and books to follow telling the same anecdote; the most-cited version being the retelling found in his 1971 *Scientific American* article 'Energy and Information', co-written with American physicist Edward McIrvine, wherein they state:[56]

> "What's in a name? In the case of Shannon's measure the naming was not accidental. In 1961 one of us (Tribus) asked Shannon what he had thought about when he had finally confirmed his famous measure. Shannon replied: 'My greatest concern was what to call it. I thought of calling it 'information', but the word was overly used, so I decided to call it 'uncertainty'. When I discussed it with John von Neumann, he had a better idea. Von Neumann told me, 'You should call it **entropy**, for two reasons. In the first place your uncertainty function has been used in statistical mechanics under that name. In the second place, and more importantly, no one knows what entropy really is, so in a debate you will always have the advantage."

Tribus recounted the incident again, in his 1987 article 'An Engineer Looks at Bayes', as follows:[57]

> "The same function appears in statistical mechanics and, on the advice of John von Neumann, Claude Shannon called it 'entropy'. I talked with Dr. Shannon once about this, asking him why he had called his function by a name that was already in use in another field. I said that **it was bound to cause some confusion** between the theory of information and thermodynamics. He said that Von Neumann had told him: 'No one really understands entropy. Therefore, if you know what you mean by it and you use it when you are in an argument, you will win every time.'"

Bound to cause confusion indeed—we might well compare this bound confusion to Shelley's *Prometheus Unbound*, and the torments and suffering of the Greek mythological figure Prometheus at the hands of Zeus.

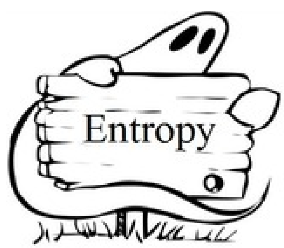
Truncated and or reformulated variations of the above have been retold ever since.[3] In short, Neumann told Shannon: 'you should call your information measure 'entropy' because nobody knows what entropy really is so in a debate you will always have the advantage.'

In regards to questions of 'historical correctness', such as raised by Harremoes—editor of the journal so-named *Entropy* that purports to be flagship of Shannon entropy—of the famous Neumann-Shannon entropy conversation, as information theorists frequently like to assert, owing to their own insecurities as to the questionable foundations of their bread and butter, the author in 2012 discussed the matter with Tribus' daughter Kammy *via* phone—Tribus himself having recently had a stroke and being in poor condition, at the age of 91, to discuss the matter himself—who comments her opinion on the anecdote that:[160]

> "**If he published it, it's true**; he may have embellished things a bit, but nevertheless if he published it it's true!"

Here we are going to side with opinion of Kammy, and with the multi-published word of Tribus, and with the tape recorded 1982 interview comment by Shannon, that in 1940 Neumann told Shannon to call his newly-forming transmission of information theory by the name 'entropy'. Multiple interview question avoidances, in regards to later queries about this etymological matter, by Shannon, discussed below, only act to strengthen this conclusion.

In any event, that 'nobody knows what entropy really is' certainly has a grain of truth to it as evidenced by the famous 1902 to 1907 'What is Entropy Debate', during which time forty odd contributions to the debate appeared in the columns of four London engineering periodicals, all of them from the pens of prominent men, such as Henri Poincare, Max Planck, and Oliver Heaviside; or the late 19th century descriptions of entropy as a 'ghostly quantity' (John Perry, 1889) or 'mathematical spook' (Max Planck, 1889), 'mixed-up-ness' (Willard Gibbs, 1903), etc., which gives credit to the humorous aspect of the joke:



but that because of this disagreement or lack of clarity of definition that one should haphazardly apply the term *entropy*—or 'transformation content' (Clausius' alternative name) or 'transformation equivalents' (Maxwell's interpretation)—to any and all situations of argument results but to make many become the butt of the joke.[58] The 'exact' original pre-inequality years definition of entropy, to clarify, is defined by the following expression:

$$N = -\int \frac{dQ}{T}$$

where N is the *equivalence value* of all *uncompensated transformations*—an early prototype synonym for entropy increase—occurring in a cycle of operations, the precise nature of this variable N being explained in Clausius' 1854-56 so-called 'principle of the equivalence of transformations'.[157] The governing rule of this equation is that N equates to zero for a reversible process and has a positive numerical value for non-reversible processes. Because, however, the exact nature of this N involves internal work-transforming-into-heat and heat-transforming-into work aspects, of the system molecules acting upon each other, we are thus barred from complete and exact measure of *N*—becoming microscopic Heisenbergians in a sense—reduced instead to the resulting macroscopic conclusion that *entropy*—or the rather the magnitude of this *N* value—tends to increase until equilibrium is reached, at which point it has a maximum value.

The interviews

Of interesting note, in regards to Harremoes' questioning of the authenticity of the Tribus-version of the alleged Shannon-Neumann conversation and assertion that Shannon culled the namesake entropy from formulas he had learned as an engineering student *before* he met Neumann, the following is a 1982 tape-recorded interview Q&A with Shannon by interviewer American communications engineer Robert Price.

Here, before reading the following responses, in regards attempts to discern whether in Shannon's response evasiveness, in answering queries about where he gleaned the entropy name, if he is lying or hiding something, in his seeming evasiveness to certain queries, we should keep in mind that Shannon was aged sixty-six at this point, in early stages of Alzheimer's disease—a 'memory' loss disease—that would eventually claim his end nineteen years later. Shannon biographer William Poundstone puts the year *circa* 1975 as the point when the disease began to grip his mind: 'from 1958 through 1974, [Shannon] published only nine articles. In the following decade, before Alzheimer' disease ended his career all too decisively, [his] total published output consisted of a single article.'[27] The following is the entropy-related digression of the interview, subtitled 'Thermodynamics and Entropy; Cryptography', brought out by questions about Norbert Wiener's possible influence on Shannon, in regards to adoption of the entropy term:[28]

> **Shannon:**
> Well, let me also throw into this pot, Szilard, the physicist. And von Neumann, and I'm trying to remember the story. **Do you know the story** I'm trying to remember?
> **Price:**
> Well, there are a couple of stories. There's the one that Myron Tribus says that von Neumann gave you the word entropy, saying to use it because nobody, you'd win every time because nobody would understand what it was.

To interject here, we see Shannon specifically pulling the names Leo Szilard, making a reference to Szilard's 1922 Maxwell's demon based $log_e 2$ derivation of demon entropy memory dissipation, and John Neumann, whom Shannon worked with between fall 1940 to spring 1941 during Shannon's postdoctoral year at the Institute for Advanced Study, Princeton, New Jersey, where at Neumann, according Shannon's 1961 in-person discussion with Myron Tribus (according to Tribus), told him to call his new log-based probability formulation by the namesake 'entropy', out of the blue in regards to the origin of the entropy etymology story. Shannon then evasively laughs for two responses, in a row, without comment—seeming to hide something:

> **Shannon:**
> [laughs]
> **Price:**
> And furthermore, it fitted p*log(p) perfectly. But that, but then I've heard . . .

Shannon:
von Neumann told that to me?
Price:
That's what you told Tribus that von Neumann told that to you.

The fitting thing for Shannon to do here would be simply to say either: 'No, Neumann did not tell that to me', or 'Yes, Neumann did tell that to me'. Such frank forthcomingness would certainly work to end the whole Shannon affair (Sokal affair) once and for all. For whatever reason, however, we see Shannon giving into evasive tactics in regards to where he got the name entropy for his transmission of information equation?

Now, supposing, for the sake of argument, that Shannon isn't lying here, namely that the alleged 1940 Neumann-Shannon 'what should I call my equation?' conversation never took place at all, we are then at great pains to explain why it so happens that in Norbert Wiener's 1948 transmission of information equation—in his *Cybernetics* (equation 3.05), published a few months after Shannon's paper appeared—an equation basically the same as Shannon's equation (*H* function), albeit in integral form, and with opposite sign, which Wiener describes as a 'reasonable measure of the amount of information, whether in the computer laboratory or in the telephone circuit', stating specifically that his new information measure is also the 'negative of the quantity usually defined as entropy in similar situations', an equation and statement that he specifically cites, via footnote, as: 'here the author makes use of a personal communication of J. von Neumann.'[60] Wiener, in short, consulted Neumann, whom he had been in contact with since as early as 1937, in the development of his transformation of information equation, which he calls entropy. Tribus states that he interviewed Shannon about this, during which time he told that he also consulted Neumann, whom he had been in contact with since 1940, in the development of his transmission of *mutual information* equation, which he also calls entropy. For some reason, however, Shannon, in the above interview, is not willing to clear the air in this matter?

This evasiveness, moreover, is compounded by the fact that in 1947 American neuroscientist Warren McCulloch mailed Shannon a copy of Wiener's 1946 special conference session 'Teleological Mechanisms' keynote address, given to the New York Academy of Sciences, wherein Wiener specifically defines information as being the negative of entropy, and goes on to quantify the amount of information being conveyed through telephone lines or nervous tissue as 'number of digits [being] the logarithm to the base 2', a measure of information theory, about which he consulted with Neumann on.[73] So even if the Neumann-Shannon conversation never took place, which would mean that Tribus fabricated the entire anecdote, which is doubtful, Shannon would still gotten the namesake entropy from Neumann via reading Wiener's 1946 keynote address. To continue:

Shannon:
[laughs – both talking at once]
Price:
Bell Labs too, that entropy could be used. That you already made that identification. And furthermore in your cryptography report in 1945, you actually point out, you say the word entropy exactly once in that report. Now this is 1945, and you liken it to statistical mechanics. And I don't

> believe you were in contact with von Neumann in 1945, were you? So it doesn't sound to me as though von Neumann told you entropy.

This evasiveness, as Brazilian electrical engineer and information theory historian Erico Guizzo, who did his MS thesis on this subject at MIT, has discerned, by study of other Shannon interviews (Friedrich Hagemeyer interview, 1977; *Omni* interview, 1987), is common when he is probed about the origins of his usage of the term entropy or of the origin of information theory, or as Guizzo puts it: 'Shannon always seemed to evade this kind of question.'[15]

Here, also, to clarify, we see Price getting his dates wrong: namely Shannon, as discussed, had been acquainted with Neumann since fall 1940, when they both worked at the Institute for Advanced Study, Princeton, New Jersey, and where at Shannon viewed Neumann, as he would state in retrospect, as being the 'smartest person he had ever met', above that of Albert Einstein whom he, as mentioned, introduced his first wife to, while at the Institute for Advanced Study.[2] In any event, Shannon's 1982 Price interview response to the twenty-thousand-dollar question as to whether Neumann told him to use the name entropy is:

> **Shannon:**
> No, I don't think he did.
> **Price:**
> This is what Tribus quoted.

Here, interestingly, we see Shannon outright denying, or at least saying that he 'thinks' that he did not got the entropy namesake from Neumann—though, digging into this response, there is rather large semantic difference between 'no' and 'no, I don't think so', particularly when it is coming from someone with Alzheimer's and in regards to the namesake of a centerpiece equation of a 1948 paper that brought him so many honorary degrees for the rest of his existence that he had to build a special revolving dry cleaner's rack into his house to hold all of the gowns.[26] Moreover, Tribus—who nearly flunked his 1948 PhD exam owing to this question and had been fretting the answer ever sense, especially leading up to his 1961 interview of Shannon—didn't just go on to 'quote' Shannon, but retold Shannon's interview response in different forms and in multiple publications (some being co-written articles) and symposiums for four plus decades onward (1963, 1971, 1978, 1983, 1987, 2002).[63] In this sense, is hard to believe Shannon's answer at this point, especially given number of verbalizations and publications in this period that were tooting the following hypothetical formula in regards to entropy:

$$\text{information} = \text{entropy}$$

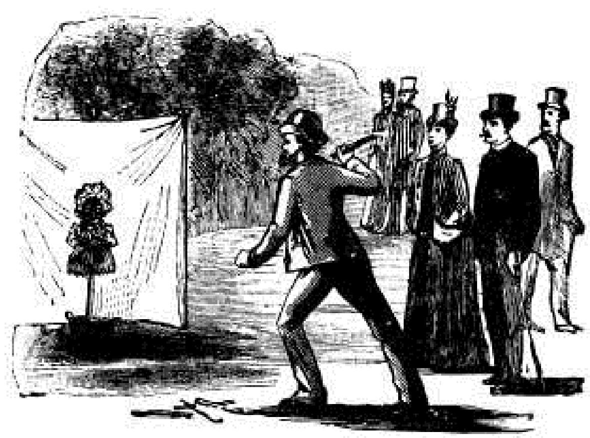
This formula, in particular, being Norbert Wiener's *circa* 1945 to 1946 version which he told to American electrical engineer Robert Fano, soon after the war ended, August 1945, in the doorway to his MIT office, specifically: 'you know, information is entropy'.[61] Hence, this could be from where Shannon, if not from Neumann, was goaded into using the term 'entropy' one time in his September 1st, 1945 classified 'A Mathematical theory of Cryptography', although this is only speculation at this point.[37] Then there is the modified negative sign version published near the end of the decade by both Norbert Wiener (1948) and Leon Brillouin (1949):

$$\text{information} = -\text{entropy}$$

This, to keep things in perspective, is not to mention the better known 'what is life?' version extolled by Austrian physicist Erwin Schrodinger (1943):[61]

$$\text{food} = -\text{entropy}$$

Which was the equation that originally inspired Wiener, supposedly, to make the connection between negative entropy and information and later Brillouin to attempt to make a connection between Wiener, Schrodinger, life, and the second law.[159] In any event 'I set up these [three] bald [equation] statements', using the fitting words of English electrical instrument maker Sydney Evershed, in regards to his 1903 listing of mostly incorrect misinterpretations of entropy, in a January 9th letter to London-based journal *The Electrician*, in connection to the great 1902 to 1904 *What is Entropy Debate*, 'as so many Aunt Sally's for anyone to shy at.'



The term "Aunt Sally" is often used metaphorically to mean something that is a target for criticism (such as the previous three entropy equations). In particular, referring to the fairground origins, an Aunt Sally would be "set up" deliberately to be subsequently "knocked down", usually by the same person who set the person up.

Here we are beginning the consortium of mess that was stewing in the 1940s, in regards to the different ways the name 'entropy' was being bandied about as the quick solution to a number of various questions.

"[We] do not feed on *negentropy* [like] a cat laps up milk."
— Linus Pauling (1987)

Of course, you have to have intellectual balls to knock down a scientific aunt sally, as we see American chemical engineer Linus Pauling has—above quote—in his sharp knockdown derailing of Schrodinger's negative entropy theory of life.[82]

In any event, given the above, is information: (a) entropy, (b) negative entropy, or (c) food? Again, just as was the case with Tribus (1948), we might very well ask this very same question to today's graduate student engineers, during their PhD exams, and no doubt all would do poorly (unless of course they had read this article first). The answer is none of the above. Entropy is a mathematical formulation of a heat quantity, nothing more nothing less. To put the question—that Tribus was specifically asked during his PhD exam, i.e. what does Clausius entropy, below left, have to do with Shannon entropy, below right—in formulaic terms, using the above 1949 Wiener-Brillouin interpretation of entropy, we are, in a very direct sense, asking the following question:

Clausius entropy Shannon entropy

$$\frac{dQ}{T} \quad \overset{?}{\leftrightarrow} \quad -K\sum_{i=1}^{n} p_i \log p_i$$

Said another way, as Israeli science philosophers Meir Hemmo and Orly Shenker put it, in their 2006 article 'Von Neumann's Entropy Does Not Correspond to Thermodynamic Entropy':[165]

> "Von Neumann's argument does not establish the desired conceptual linkage between $\mathrm{Tr}(\rho \log \rho)$ and thermodynamic entropy $\frac{1}{T}\int pdV$."

Our aim here, to clarify, is not to delve into the validity of Neumann's entropy equation, at this point, but rather to highlight the fact that derivation jumping is a path on weak footing.

The left equation (Clausius entropy), an absolute temperature divided heat differential going into our out of a system, to conclude, has NOTHING to do with the right equation (Shannon entropy), a summation of probabilities of strings of binary numbers coming out of a communication line. That people would believe that the two have anything to do with each other is what happens when equations ($\frac{dQ}{T}$) get translated into English (entropy), then back again into another equation (Boltzmann *H* function), then back again into English (Boltzmann entropy), then back again into another equation (Szilard-Neumann entropy), than back again into English (entropy of the measurement process), then back again into another equation (Shannon *H* function), then back again into English (Shannon entropy/Shannon information), wherein, during the course of each translation, the fine print of the original equation (Clausius) gets left behind, scattered about in the various mistranslation steps—in the same way a Xerox of a Xerox of Xerox become less recognizable in each copying step or in the same way that a clone of a clone of clone, such as in the 1996 film *Multiplicity*, becomes more mentally retarded in each recloning step.

To continue, none of Shannon's 1982 answer corroborates with the fact that Fano specifically credits his early interest in information theory to Wiener—who got his entropy ideas from Neumann (who got his entropy ideas from Szilard)—and Wiener's cryptic office doorway comment, and how in the years to follow Fano tried to make sense of that cryptic comment, and how this led Fano to develop, independently, the first theorem of Shannon's theory, about which Shannon specifically asked him to publish quickly, so that he could cite the work in his 1948 groundbreaking paper. All of this directly links Shannon through Fano through Wiener to Neumann who got his 'information [has something to do with] entropy' ideas Szilard, his close home countryman Hungarian friend, and his 1922 demon memory entropy arguments. So even if Shannon wants to deny that he talked to Neumann about this directly, and deny that he talked to Tribus about this, and deny that he never read the 1946 Wiener keynote address, he still talked to Neumann about entropy *indirectly* via Fano.[62]

In any event, barring prolonged digressing on the merits and comparisons of these three pop-science entropy or 'negentropy equations', as Brillouin liked to call them, which is a discussion in and of itself, beyond the scope of the present article, to continue with the 1982 Price interview:

> **Shannon:**
> Yeah, I think this conversation, it's a very odd thing that this same story that you just told me was told to me at Norwich in England. A fellow —
> **Price:**
> About von Neumann, you mean?
>
> **Shannon:**
> Yeah, von Neumann and me, this conversation, this man, a physicist there, and I've forgotten his name, but he came and asked me whether von Neumann, just about the thing that you told me, that Tribus just told you, about this fellow. . .
> **Price:**
> That was Jaynes, I imagine the physicist might have been [Edwin] Jaynes.

Here again we see Shannon beyond evasiveness, using the word 'yeah', which is a blend of yes and no, which, according to the *Urban Dictionary*, is 'used to delay a particularly embarrassing moment or if [one is] lost for words, like uh', fumbling around, barely able to get his words out, about the word (entropy) for the equation he is best known for—and to be clear, this was not the first time he was asked this probing question in interview. In his previous 1977 interview with German graduate student science historian Friedrich Hagemeyer, which is not yet available in printed English, also recorded on tape, as was this one with Price, Shannon, when asked about his knowledge about entropy in regard to Norbert Wiener's usage of entropy, responds:[64]

> "I think actually Szilard was thinking of this, and he talked to von Neumann about it, and von Neumann may have talked to Wiener about it. But none of these people actually talked to me about it before I was thinking of this myself."

Yet in the very same 1977 interview, Shannon states that he specifically read Wiener's 1942 classified yellow peril report which contains Brownian motion discussions (what Szilard's demon articles is based on), discussed in the context of filtering noise out of received signal—Shannon's work dealing with overcoming noise in a signal transmission—with 'with interest'.[118] So even if Shannon is outright lying (or being Alzheimeric) about the 1940 Neumann conversation, he would have at the very least known about Einstein-based Brownian motion precursory entropy ideas from Wiener in 1942, who was one of his professors, or at the very least known about Warren's use of the term entropy via Shannon's co-author associate Warren Weave, the direct supervisor of Wiener's work.[52] But then again, the relationship of Shannon's information theory to Wiener, as American physical economics historian Philip Mirowski puts it, 'is a bit difficult to interpret.'[52]

To continue, with the 1982 interview, Price then brings up the symposium book *Maximum Entropy Formalism*, held at MIT on May 2-4, 1978, centered around the work of American physicist Edwin

Jaynes (1957) and based on his work, the work of engineer Myron Tribus (1960s-2000s) and their grasping attempts to bridge information theory with statistical thermodynamics *via* Shannon:[65]

> **Shannon:**
> Yes, I think it was, I think so. Do you know him?
> **Price:**
> Well, he's published in the same book as Tribus, you see. This is a book called *The Maximum Entropy Formalism*. You've probably seen that book, but they have chapters in it, and Jaynes, the physicist —
>
> **Shannon:**
> Now, I'm not sure where I got that idea [entropy], but **I think I, somebody had told me that**. But anyway, I think I can, I'm quite sure that it didn't happen between von Neumann and me.
> **Price:**
> Right. Well, I think that the fact that it's in your 1945 cryptography report establishes that, well, you didn't get it from von Neumann, that you had made the p*log(p) identification with entropy by some other means. But you hadn't been —

Here again we see outright word fumbling—'But anyway, I think I can, I'm quite sure'—wherein he lets out the Freudian slip that 'somebody told me', in regards to where he got that idea (entropy). Shannon, in these different interviews, seems to be barely able to keep his facts together. To continue:

> **Shannon:**
> Well, that's an old thing anyway, you know.
> **Price:**
> You knew it from thermodynamics.
>
> **Shannon:**
> Oh, yes, from thermodynamics. That goes way back.
> **Price:**
> That was part of your regular undergraduate and graduate education of thermodynamics and the entropy?
>
> **Shannon:**
> Well, not in class, exactly, but I read a lot, you know.

At least he's got this last concluding remark straight: electrical engineers and mathematicians *don't* take thermodynamics classes. The comment 'Oh, yes, [I got it] from thermodynamics' and his speaking of the Neumann conversation as an 'old thing anyway' is a dead giveaway that Shannon is hiding something—which, as the *Urban Dictionary* classifies, in regards to those who use the term 'yeah' in response to awkward questions, is likely something that to Shannon is an embarrassing moment, namely the 1940 Neumann conversation.

Lastly, to note, there also is a 1953 *Forbes* magazine interview, written by Francis Bello, wherein it is stated to the effect that Shannon derived his equation for the amount of information, and later found that it was identical to the formula that physicists use to calculate entropy; the author, however, has not as of yet obtained this interview, but again this is but the fool's argument—and, again, is not something that corroborates with the Tribus retelling of the Shannon entropy etymology.[66]

To conclude, herein, as it is a published fact that Neumann told Wiener to call his equation by the name entropy, we are going to side with published word of Myron Tribus that Neumann was also the one who told Shannon to call his equation by the name *entropy*—a name that seemed to be in the air, at least in the works of Wiener (1946) and Brillouin (1949), and before them at the Institute for Advanced Study in the works of Einstein (1905), Szilard (1922), and Neumann (1927/1932), during the tense and energized war time classified years centered around Shannon's information/cryptography work at Bell Labs—as a joke. Indeed the joke has been on us—it has forced us to tighten our intellectual belts in regards to our understanding of heat.

To give Shannon some credit here, we do note that he wrote the main parts of his information theory at home, in his spare time, as a hobby, recalling the writing of the 1948 paper as painful, and insisting that he had developed the theory out of pure curiosity, rather than a desire to advance technology or his career.[17]

In any event, at the present writing, a conservative estimate would indicate that over a 100 or more butt of the joke stylized articles and or books—if not more than a thousand, per year, are written solely based on the above Neumann suggestion—a sad fact of the way in which ignorance easily spreads, particularly among the gullible—or more correctly those uneducated in both thermodynamics, statistical mechanics and communication engineering, which includes nearly everyone, give or take a few. The 1990 book *Social Entropy Theory*, by American sociologist Kenneth Bailey, gives an idea of the unaware usage of this joke-based theory among sociologists, by the dozens. The 2002 book *Maxwell's Demon 2*, boastfully lists references to more than 550 of these types of Shannon-themed thermodynamics publications.[67] The online journal *Entropy* was launched in 1999 by Chinese-born Swiss chemist Shu-Kun Lin owing to his own confusions over the nature and difference between, specifically *thermodynamic entropy* (Clausius, Gibbs, Boltzmann, Planck type), *Prigogine entropy* (dissipative structure theory type), and *Shannon entropy* (information theory type), as he fully discusses in the journal's debut editorial article 'Diversity and Entropy'. The confusion has only grown moreso since its launching.

Lin's idea was that the journal was serve as forum to, as he says, 'investigate whether the information-theoretic entropy and the thermodynamic entropy are compatible or not', reasoning that in the long run publishing high quality papers in 'physics, chemistry, economics, and philosophy', on this compatibility question, would, in his own view, 'make the life of the students of younger generations easier, entropy related concepts being [hence forth] clarified and well defined'.[66] This, however, has not occurred—author submissions to this journal are required to bring their 'own' peer review referees, not independent referees, and as a result the *Entropy* journal has become a proving ground for empty papers largely in information theory mathematics, under the hollow flagship thermodynamic banner 'entropy', currently chiefed by American mathematical physicist and neuroscientist Kevin Knuth, who, as can be gleaned from his curriculum vitae, seems to have almost no formal training nor publication history in thermodynamics, and as such is the captain of a ship, that boasts a misleading and very ambiguous flag, on an uncharted voyage to who knows where.[69] This, to clarify, is not *ad hominem*, but rather the act of pointing out the irony of having someone edit a journal entitled 'entropy', who likely has never read

German physicist Rudolf Clausius' 1865 textbook *The Mechanical Theory of Heat*, wherein the term entropy is defined, but who instead steers his ship based on readings of American electrical engineer Claude Shannon's *The Mathematical Theory of Communication*.

A History of Memorandum Warnings

It is a greatly unusual practice, in scientific writing, to cap lock, italicize, underline, bold, colon, and exclamate text—let alone the abstract of text—as well as being highly unusual to pictorialize an abstract in near-childlike manner, but such is the ridiculous situation here: a *circa* 1939 joke turned 2039 vacuous science. Yet, on the other hand, sometimes cap lock words serve a decisive purpose. They make us stop and think. Sometimes a single caplocked word can bring about a revolution in science. This can be exemplified by the following 1798 concluding synopsis paragraph by American-born English physicist Benjamin Thompson of the results of his famous caloric theory questioning cannon boring experiments, which is one of the stepping stones in the etymological timeline of the coining of the term *entropy*, showing his italics and capital letter word:[70]

> "**What is heat?** Is there anything as igneous fluid? Is there anything that can with propriety be called caloric? That heat generated by friction [in the boring experiments] appeared, evidently, to be *inexhaustible*, [it] cannot possibly be *a material substance*; … it appears to me to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in the manner heat was excited and communicated in these experiments, except it be MOTION."

What is heat indeed! It certainly is NOT Boolean algebra mixed with probability theory mixed with cryptography theory as Shannon would have us believe. In fact, the term *entropy*, the solution to the above paragraph—the mathematical state function model of heat—is based on the Euler reciprocity relation in the form of partial differential equations, the coining of which, to remind us all, by German physicist Rudolf Clausius, in 1865, is as follows:[71]

> "We might call *S* the *transformation content* of the body, just as we termed the magnitude *U* its *thermal* and *ergonal content*. But as I hold it to be better terms for important magnitudes from the ancient languages, so that they may be adopted unchanged in all modern languages, I propose to call the magnitude S the **entropy** of the body, from the Greek word *τροπή*, *transformation*. I have intentionally formed the word *entropy* so as to be as similar as possible to the word *energy*; for the two magnitudes to be denoted by these words are so nearly allied their physical meanings, that a certain similarity in designation appears to be desirable."

which occurred during an April 24th reading of the article 'On Several Forms of the Fundamental Equations of the Mechanical Theory of Heat' to the *Philosophical Society of Zurich.* That Shannon was cajoled into adopting this agenda for his communications engineering problem is one of the more absurd blotches in the timeline of the history of science.

To exemplify the ongoing absurdity of this near-inane situation, thus justifying the use of accentuated grammatical presentation—a SHOUT if you will—we note, below, that there is an entire history of 'published memorandum notices' of public declarations and warnings that Shannon's conception of and usage of the namesake 'entropy', which he commandeered for his signal transmission mathematics, has absolutely nothing to do with the thermodynamic concept of 'entropy', of either Boltzmann variety, the Gibbs variety (which he called 'analogs'), or the original bedrock Clausius definition.

To put these so-called memorandum notices in historical context, to review, firstly, in 1929 and 1930, Hungarian-born American physicist Leo Szilard and American physical chemist Gilbert Lewis, respectively, published separate Maxwell's demon themed piston-and-cylinder gas system argument articles, each deriving logarithmic entropy formulations for gas particles in bi-compartment vessel, both concluding, in short, that the action of gathering measurement knowledge, or 'information' so-to-speak, about the location of a given gas particle requires that a certain amount of work be done, which generates a certain amount of entropy.[39] Secondly, Neumann, in his 1932 *Mathematical Foundations of Quantum Mechanics* is often mis-cited, specifically by American civil engineer and mathematician Warren Weaver (1949), as having 'treated information' in quantum mechanical and particle physics terms, but correctly Neumann was not thinking in communication engineering terms, but rather calculated the entropy of Gibbsian ensemble systems of light quantas, electrons, and protons, discussing the uncertainty in the measurements, in Heisenberg uncertainty principle terms. In 1942, American mathematician Norbert Weiner, in his wartime classified so-called yellow peril report 'The Interpolation, Extrapolation of Linear Time Series and Communication Engineering' (which Shannon read with interest), his 1946 Macy conference presentations, and followup 1948 *Cybernetics* book, was outlining speculative connections between entropy and the degree of randomness in a message—commenting to people, such as Robert Fano (c.1945), his view that 'information is entropy'.[73] Then, infamously, in 1949, Weaver, in a rather bloated footnote, full of misrepresentation and misattribution, to the opening of his *The Mathematical Theory of Communication*, the second chapter co-authored by Shannon, gave the following rather attack-buffering historical platform, wherein he convolutes all of the above together as though it is the same essential theory:[224]

> "Shannon's work roots back, as von Neumann has pointed out, to Boltzmann's observations, in some of his work on statistical physics (1894), that entropy is related to 'missing information', inasmuch as it is related to the number of alternatives which remain possible to a physical system after all the macroscopically observable information concerning it has been recorded. Leo Szilard (*Zeitschrift fur Physik*, Vol. 53, 1925) extended this idea to a general discussion of information in physics, and von Neumann (*Mathematical Foundation of Quantum Mechanics*, Berlin, 1932, Chap V) treated information in quantum mechanics and particle physics. Shannon's work connects more directly with certain ideas developed some twenty years ago by Harry Nyquist and Ralph Hartley, both of Bell Laboratories; and Shannon has himself emphasized that communication theory owes a great debt to Norbert Wiener for much of its basic philosophy [cybernetics]. Wiener, on the other hand, points out that Shannon's early work on switching and mathematical logic antedated his own interest in this field; and generously adds that Shannon certainly deserves credit for independent development of such fundamental aspects of the theory as the introduction of entropic ideas. Shannon has naturally been specially concerned to push the applications to engineering communication, while Wiener has been more concerned with biological applications (central nervous system phenomena, etc.)."

This is historical obfuscation at its best. Firstly, as discussed, the '*Zeitschrift fur Physik*, Vol. 53' is a 1929 publication, not a 1925 publication. Possibly Weaver here was convoluting the 1925 date of acceptance of the original 1922-written Szilard demon paper by the University of Berlin as his habilitation with the 1929 journal publication. This is a trivial matter. More importantly, however, since we are attempting herein to dig out the rotten roots of the information theory entropy myth, we see the entire 'Shannon's work is based on' polemic using the shunned upon *recourse to authority* method—i.e. 'as von Neumann has pointed out' (another baseless *ad nauseam* repeated phrase)—which, as Vincenzo Galilei taught his famous son, Galileo, in the year *circa* 1570, is unbecoming:

> "Those who rely simply on the weight of authority to prove any assertion, without searching out the arguments to support it, act absurdly. I wish to question freely and to answer freely without any sort of adulation. That well becomes any who are sincere in the search for truth."

Or as Italian polymath Leonardo da Vinci put it about a half-a-century earlier said: 'anyone who conducts an argument by appealing to authority is not using his intelligence; he is just using his memory'. The point here is that the assertion, made by Weaver, supposedly 'pointed out by Neumann', that Boltzmann observed in 'some of his 1894 statistical work' that entropy is related to 'missing information', as far as the author has been able to track down, is but a case of pure misattribution—similar to the way modern information theorists tend to misattribute Szilard has having 'calculated the cost of information in bits'.[145] All of Boltzmann's 1894 paper, according to reference section of his 1898 *Lectures on Gas Theory*, and as far as the author is aware, as listed below, are focused on the kinetic theory of gases in relation to temperature:

Paper	Source
"About Determining the Absolute Temperature" ("Über ide Bestimmung der absoluten Temperatur")	*Mun. Ber.* 23, 321; in: *Ann. Physik* [3] 53, 948, (1894; Abh. 3, 490.
"On the Application of the Determinantal Relation to the Kinetic Theory of Polyatomic Gases"	*Brit. Associ. Rept*. 64, 102; Abh. 3. 520.
"On Maxwell's Method of deriving the Equations of Hydrodynamics form the Kinetic Theory of Gases"	*Brit. Assoc. Rept.* 64, 579; Abh. 3, 526.
"On the Evidence of the Maxwell Velocity Distribution of Gas Molecules Under the Law" ("Über den Beweis des Maxwellschen Geschwindigkeitsverteilungsgesetzes unter Gasmolekülen")	*Mun. Ber.* 24, 207; *Ann. Physik* [3] 53, 955.

Beyond this, no pre-1949 mentions of mentions of Boltzmann discussing 'missing information', in either English or German, are to be found in Google Book searches; and all post-1949 mentions of Boltzmann speaking of entropy as 'missing information' cite back to the above Weaver footnote. American civil-ecological engineer Jeffrey Tuhtan, who has read through a large number Boltzmann's works in the original German, comments on this issue:[74]

> "I looked through *Polulaere Schriften* [*Popular Writings*], but could not find any articles from 1894. I don't recall the word "information" being often used in older works in German, and I have a decent

collection of original German publications to choose from (Schroedinger, Planck, Helmholtz, Ostwald, etc.)."

In any event, in regards to both the 1949 Weaver footnote, on the apocryphal miscitation of Boltzmann thinking about entropy as 'missing information', and the 1949 Neumann automaton lecture, on the misaligned notion that each bit has a certain k ln 2 units of entropy associated with it, we see a lot of 'pointed out by Neumann' justification going on here, which is certainly no way to go about conducting science.

Historical mis-attributions, in information theory publications, as noted previously in the examples of Seth Lloyd (2006) and Robert Doyle (2011), are common, especially in over-zealous information theory platformed agenda writings. This is what we have in the Weaver footnote: a twisting of things around—a habit common to information theorists who a longing desire to dabble in thermodynamics.

One has to be an expert in a number of different fields to see though the smoke of the Weaver footnote. Shortly thereafter, Shannon and Weaver's *The Mathematical Theory of Communication*, with the above misrepresentative historical footnote, quickly became a best-seller: over 51,000 copies were sold between 1949 to 1990; and it is currently cited in Google Scholar by over 54,000 publications; and so it came to pass, in the minds of the uninformed, that Shannon entropy and Boltzmann entropy and Clausius entropy are one in the same, which is NOT the case, in any sense of the matter. This is what is called a scientific myth.

The Russian editor to the 1953 Russian translation of Shannon's 1948 article 'A Mathematical Theory of Communication', wherein the loaded Neumann-Shannon joke was first unleashed, an article which the editor retitled clearly and unambiguously as 'The Statistical Theory of Electrical Signal Transmission', was the first to issue an *editorial warning* that the terms and equations used by Shannon have nothing to do with thermodynamics.[76] The editor's preface reads as follows:[77]

> "The terminology of the statistical theory of electrical signal transmission and a number of its concepts are utilized by some foreign mathematicians and engineers in their speculations related to the notorious 'cybernetics'. For example, building upon **superficial, surface analogies** and **vague, ambiguous terms and concepts**, Wiener, Goldman, and others attempted to transfer the rules of radio communication to biological and psychological phenomena, to speak of the 'channel capacity' of the human brain, and so on. Naturally, such attempts to give cybernetics a scientistic look with the help of terms and concepts **borrowed from another field** [thermodynamics] do not make cybernetics a science; it remains a pseudo-science, produced by science reactionaries and philosophizing ignoramuses, the prisoners of idealism and metaphysics. At the same time, the notorious exercises of philosophizing pseudoscientists cast a shadow on the statistical theory of electrical signal transmission with noise—a theory whose results and conclusions have great scientific and practical importance."

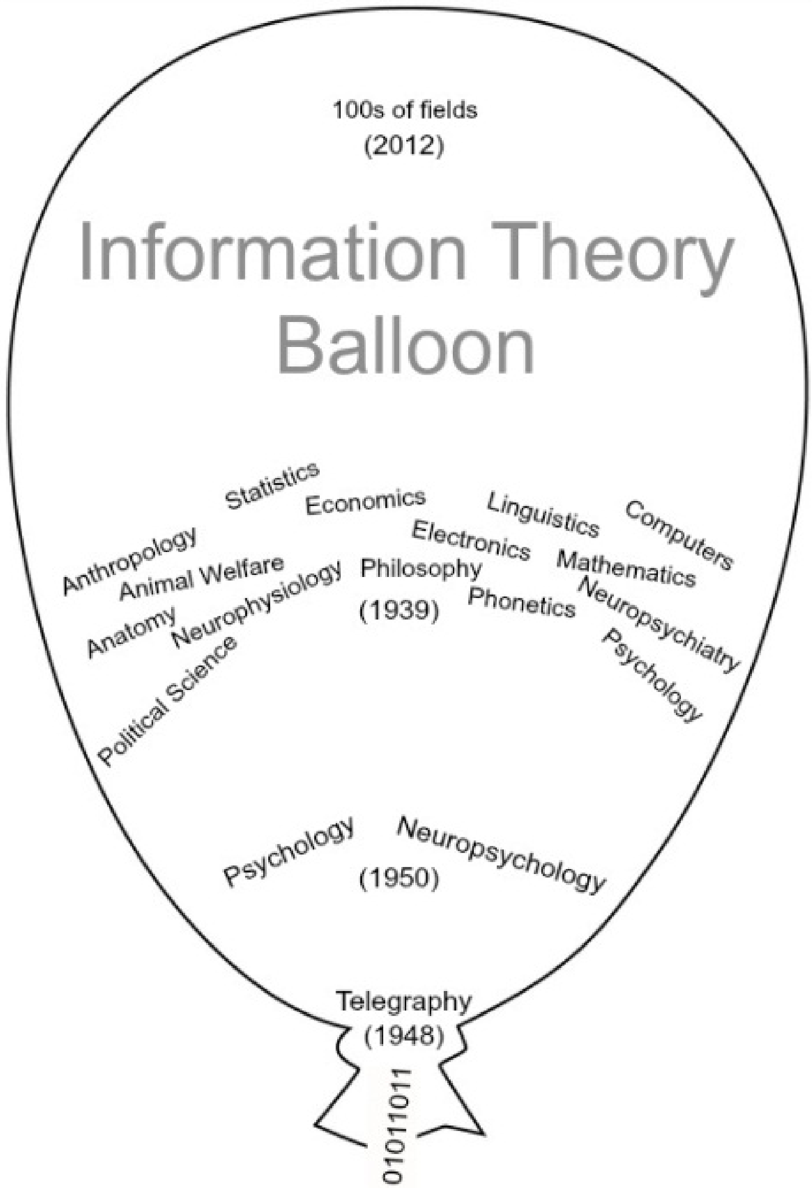
The mention of Goldman here is a reference to be American electrical engineer Stanford Goldman, who in his 1953 book *Information Theory*, defined as an introductory treatment for students of electrical engineering and or applied mathematics, digresses at one point in the book on the second law, wherein he misattributes, similar to Lloyd (2006), Maxwell, Boltzmann, and Gibbs as all having 'realized there was a close relation between entropy and information'.[78] Again, a twisting of things around: Maxwell, Boltzmann, and Gibbs NEVER considered there to be a close connection between entropy and information. Information and information theory are not 19th century concepts. Shannon, in fact, didn't coin the term 'information theory' until 1945, as found in his cryptography report. Maxwell, originally, had such an off understanding of entropy—because he initially culled his understanding of it from his friend Scottish physicist Peter Tait (*Sketch of Thermodynamics*, 1868)—that he had to issue a retraction in the fourth edition of his famous *Theory of Heat*; Boltzmann understood entropy in terms of velocity distributions and molecular disorder; Gibbs conceived of entropy, in his unpublished writings as 'mixed-up-ness'.[79]

Goldman then goes on to make a jabbing attempt to convolute and reinterpret Boltzmann's particle velocity distribution *H* function such that *H* can also represent the 'average language information per symbol or per message', which of course is but an example of someone completely lost in the equations of science as a whole—or at least barred from clarity owing to an interscience two cultures divide.[81]

In short, to continue, in the above Russian edition editorial warning, the Russian editor is saying that Shannon convoluted the statistical theory of electrical signal transmission with noise together with the statistical theory of thermodynamics of gas system behaviors solely to give his new theory a scientific look and thus to bolster his reception, but resulting, in the end, only to cast a large shadow on the working fruits of his theory, namely the development of the equations of communications engineering, radio wave communication theory, telegraphy, and radar detection science, in particular.

Immediately following the publication of Shannon's 1948 treatise 'A Mathematical Theory of Communication', applications were soon being made into fields outside of communication engineering, by radio or wire, theory. In the first London symposium on information theory, held in 1950, six out of twenty papers presented were about psychology and neurophysiology. This number increased to eight by the time of the second symposium.[32] By the third symposium held in 1956, the scope was so wide that it included participants with backgrounds in sixteen different fields: anatomy, animal welfare, anthropology, computers, economics, electronics, linguistics, mathematics, neuropsychiatry, neurophysiology, philosophy, phonetics, physics, political theory, psychology, and statistics.[83] This was followed, soon thereafter, by applications of information theory in: semantics, garden design, quantum mechanics, management, visual arts, religion, oral speech, theater, pictorial arts, ballet, among other subjects of human behavior.[27]

The following information theory balloon depiction gives an idea of this 'ballooning effect', as Shannon would later describe it (1956), along with a representative quote by American engineer Myron Tribus as to why it was so easy for the balloon to fill up so fast—namely because people were using Shannon to skip over the hundreds of equations of thermodynamics to quickly reach unfounded conclusions:[84]



"Should an attempt be made to extend our interests to such fields as management, biology, psychology, and linguistic theory, or should the concentration be strictly in the direction of communication by radio or wire?"

— L.A. De Rosa, "In Which Fields Do We Graze? (1955)[85]

"Once, during a presentation at IIT in Chicago, I showed how Edwin Jaynes' [information theory] methods developed, in four lines, the equations Fowler and Guggenheim [*Statistical Thermodynamics*] required hundreds of pages to reach. The presentation did not convince the audience. Their reaction: surely we had cheated somewhere."

— Myron Tribus (1998)[43]

In other words, with Shannon's simple probability equation, people no longer needed to read through the hundreds of equations of statistical thermodynamics, but now could quickly theorize thermodynamically about whatever he or she desired—hence the balloon quickly filled, Shannon based arguments could be made, and funding was soon being misappropriated on baseless arguments.

In 1955, in the midst of this growing or rather ballooning application of information theory, L.A. De Rosa, chairman of the newly formed Professional Group on Information Theory (PGIT), published the following query memo, attempting to get an handle as to which direction the PGIT was headed, in regards to research, funding, and publication types to be accepted:[85]

In Which Fields Do We Graze?

L. A. DE ROSA
December 1955
Chairman, Professional Group on Information Theory

THE EXPANSION of the applications of Information Theory to fields other than radio and wired communications has been so rapid that oftentimes the bounds within which the Professional Group interests lie are questioned. **Should an attempt be made to extend our interests to such fields as management, biology, psychology, and linguistic theory, or should the concentration be strictly in the direction of communication by radio or wire?**

To make one's interest the formulation and extension of the general theory of information, and then, having armed oneself with such a universal and powerful tool, to consider only those applications which deal with radio and wire communication, is an attitude which has been criticized by a number of our members.

Other Professional Groups whose interests lie in more sharply defined fields must, perforce, consider the application of Information Theory to their respective fields; otherwise, the benefits which may accrue through the extension of Information Theory to these various specialized fields might occur belatedly, or not at all.

Some of our members argue that should the application of Information Theory to other specialized fields be left to their specialists and the interests of PGIT not extend to fields other than radio and wire communication, then PGIT would be a purely academic and theoretical group with no interests in any but the general, universally applicable, mathematical procedures.

We have heard the opposite views expressed also, namely that PGIT should encourage the extension of the theorems to other general fields and broaden the scope of PGIT to include the interests of Psychology, Biology, and other branches of the "Arts and Sciences." In so doing, it is argued, PGIT becomes a creative group in advancing the theory of information and in assisting other Professional Groups. Thus, by disseminating information of other fields which may be required for the over-all solution of the problem of communication from one subjective sensory terminal to another (the over-all "brain-to-brain" terminals), a *raison d'être* is established for us.

At least one more group feels that PGIT should confine itself to adapting the generic developments of Information Theory to the specific field of radio, electronics, and wire communication, foregoing all ties with computers, television, telemetry, management, automation, or circuit theory.

It would be interesting to obtain the views of PGIT members with regard to the proper bounds of our interests and activities, for without such expression, proper direction cannot be achieved.

This editorial prompted a number of response articles. PGIT members were divided. Some believed that if knowledge and application of information theory was not extended beyond radio and wire communications, progress in other fields could be delayed or stunted. Others, however, insisted on confining the field to developments in radio, electrons, and wire communications. The two points of view were hotly debated over the next few years.[32]

In 1956, Shannon, wary of the intellectual destruction he had unleashed, was himself forced to issue an *editorial plea*—in the form of one-page article entitled 'The Bandwagon', reprinted in full below, calling for a more restrained application of his communications theory, *outside* of information theory proper:[84]

The Bandwagon

CLAUDE E. SHANNON

March 1956

INFORMATION theory has, in the last few years, become something of a scientific bandwagon. Starting as a technical tool for the communication engineer, it has received an extraordinary amount of publicity in the popular as well as the scientific press. In part, this has been due to connections with such fashionable fields as computing machines, cybernetics, and automation; and in part, to the novelty of its subject matter. As a consequence, it **has perhaps been ballooned to an importance beyond its actual accomplishments.** Our fellow scientists in many different fields, attracted by the fanfare and by the new avenues opened to scientific analysis, are using these ideas in their own problems. Applications are being made to biology, psychology, linguistics, fundamental physics, economics, the theory of organization, and many others. In short, information theory is currently partaking of a somewhat heady draught of general popularity.

Although this wave of popularity is certainly pleasant and exciting for those of us working in the field, it carries at the same time an element of danger. While we feel that information theory is indeed a valuable tool in providing fundamental insights into the nature of communication problems and will continue to grow in importance, it is certainly no **panacea** for the communication engineer or, *a fortiori*, for anyone else. Seldom do more than a few of nature's secrets give way at one time. It will be all too easy for our somewhat artificial prosperity to collapse overnight when it is realized that the use of a few exciting words like *information*, *entropy*, *redundancy*, do not solve all our problems.

What can be done to inject a note of moderation in this situation? In the first place, **workers in other fields should realize that the basic results of the subject are aimed in a very specific direction, a direction that is not necessarily relevant to such fields as psychology, economics, and other social sciences.** Indeed, the hard core of information theory is, essentially, a branch of mathematics, a strictly deductive system. A thorough understanding of the mathematical foundation and its communication application is surely a prerequisite to other applications. I personally believe that many of the concepts of information theory will prove useful in these other fields—and, indeed, some results are already quite promising—but the establishing of such applications is not a trivial matter of translating words to a new domain, but rather the slow tedious process of hypothesis and experimental verification. If, for example, the human being acts in some situations like an ideal decoder, this is an experimental and not a mathematical fact, and as such must be tested under a wide variety of experimental situations.

Secondly, we must keep our own house in first class order. **The subject of information theory has certainly been sold, if not oversold.** We should now turn our attention to the business of research and development at the highest scientific plane we can maintain. Research rather than exposition is the keynote, and our critical thresholds should be raised. **Authors should submit only their best efforts, and these only after careful criticism by themselves and their colleagues. A few first rate research papers are preferable to a large number that are poorly conceived or half-finished. The latter are no credit to their writers and a waste of time to their readers.** Only by maintaining a thoroughly scientific attitude can we achieve real progress in communication theory and consolidate our present position.

The reason for this editorial warning memo, is that in the course of the previous eight years, since the publication of his 1948 'A Mathematical Theory of Communication' and followup 1950 'Prediction of Entropy of Printed English, in the latter of which he estimated the so-called 'entropy' of written English to be between 0.6 and 1.3 'bits' per character—never mind that standard SI entropy units are 'J/K', for entropy increase or decrease, or 'J/K·mol', for the entropy of a chemical species in a given state—based on the ability of human subjects to guess successive characters in text, his simple to understand *logarithm of probabilities* theory, which he alleged or rather alluded to be the new universal embodiment of entropy, entropy increase, and the second law of thermodynamics, at least according to the way intellectually *naive* people—deficient in informed judgment—saw things, resulted to the drumroll effect that people by the droves were now simply citing: Shannon (1948), and going on to make hodgepodge info/thermo-blurred applications in: biology, psychology, sociology, economics, music theory, linguistics, cryptography, fundamental physics, organization theory, and gambling, to name a few, as depicted in the previous information theory balloon parody—which we aim to pop herein.

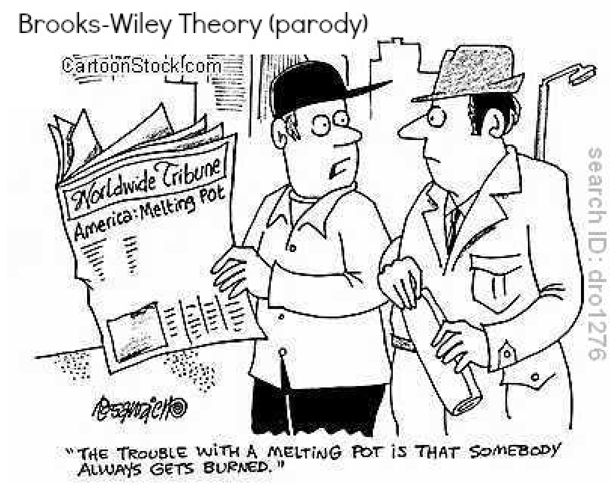
In regards to human thermodynamics, the key points the reader should take strong note of here, in this editorial warning, is Shannon's statement that his formula for data transmission theory is not applicable to psychology, economics, sociology, philosophy, and other human behavioral sciences—and that usage of his theory *outside* of signal transmission theory proper is, in his own words, 'a waste of time' to both readers and writers. The fact that the author, in recent years, has had to 'waste time' assigning required reading sections to bioengineering students explaining that Shannon entropy has nothing to do with thermodynamics—is a signal that terminology reform is greatly needed—these required reading notes, in fact, being one of the promptings to the writing of the present article.[N1]

This thermodynamics teaching issue is compounded by the fact that some thermodynamics textbook authors are in the gray area about the use or non-usage of Shannon entropy in biothermodynamics. A ripe example is American biophysicist and protein thermodynamicist Donald Haynie, who in his 2001 and second edition 2008 *Biological Thermodynamics* textbook, chapter subsection 'Energy, Information, and Life', devotes eleven pages to a digression on the incorrect view that 'information theory is closely akin to statistical thermodynamics'. Haynie even goes so far as to state the following baseless definition:[195]

> "The gain of one bit of information by a cell requires the expenditure of at least $k_B T \ln 2$ units of work: $S = k_B \ln \omega$, and the entropic term of the Gibbs free energy is *TS*. At 27℃, one bit of information costs $3 \times 10^{-21} J$."

When one traces the roots of this derivation, as we have done herein, one sees that there is absolutely no basis for this assertion, which is a Shannon juggling admixture of about five different fields together into an apparent albeit baseless conclusion. The author has even given invited guest lectures to bioengineering thermodynamics classes, where Haynie's book, with the above misinformed presentation, is one of the two required reading textbooks. Hence, the mistaken belief that Shannon entropy is thermodynamical is deeply ingrained, in the minds of many students, not to mention the minds of many professors.

The writing of the present article, in agreement with Shannon, is thus a waste of time, but one that has become a necessity, for the sake of new engineering students, to give a cogent warning heads-up to those contemplating ventures into attempts at thermodynamic formulation, outside of the heat engine proper, in fields such as economics, sociology, psychology, anthropology, business, etc. For whatever reason, as the author has frequently encountered—in the writing of over 500+ online biographies, see the 'HT pioneers' page of *Hmolpedia*, of human thermodynamics theorizers—physicists, chemists, engineers, and social scientists are lured by the droves, like moths to light, into attempts at usage of Shannon theory to connect the second law to whatever theory he or she happens to be perusing—only to get burned at end. The following parody of the 1982 Shannon entropy based Brooks-Wiley theory of evolution being one example of someone who gets burned:



A cartoon parody of the Shannon information based Brooks-Wiley evolution theory, from a 2011 article by David Tyler, portraying the theory of Canadian zoologist Daniel Brooks and American systems ecologist Edwin Wiley as a "melting pot theory" wherein, in the end, Daniel Brooks is the one who gets "burned".[86]

By 1960, the bandwagon effect had become so great that eventually Shannon was forced to withdraw from the public eye for nearly two-decades and refused to speak publically about his information theory.[25] Later, however, after things began to neutralize to some extent, Shannon began to open up, about his inside views on the matter. In a 1979 interview discussion with English-born American investigative journalist Jeremy Campbell, for example, Shannon commented:[87]

> "I think the connection between information theory and thermodynamics will hold up in the long run, but it has not been fully explored or understood. There is more there than we know at present. Scientists have been investigating the atom for about a hundred years and they are continually finding more and more depth, more and more understanding. It may be that the same will be true of the relationship we are speaking about."

Here, to note, in comparing his 1956 memorandum with above 1979 statement, paradoxically, we see that Shannon, on one hand, warns us not to use his theories *outside* of communication engineering, and yet on the other hand he still believes and tells people that his theory has some remote future connection to the laws of thermodynamics, the second law in particular, which of course applies to every physical system in the universe, but in a very specific way. Shannon is either a hypocrite or possibly defending his mistaken position till the end, owing to his general ignorance of thermodynamics, or possibly a mixture of these intertwined with his growing Alzheimer's memory loss. The playing dumb ignorance perspective seems, however, to be the dominant position of Shannon, as exemplified by the following 1987 interview Q&A with Anthony Liversidge of *Omni* magazine:[88]

> **OMNI:** Before you wrote your classic paper on *The Mathematical Theory of Communication*, Norbert Wiener [c.1945] went around the office at Bell Labs announcing 'information is entropy'. Did that remark provoke you in any way to come up with information theory?

> **Shannon:** No, I hadn't even heard of that remark when I started my work. I don't think Wiener had much to do with information theory. He wasn't a big influence on my ideas there, though I once took a course from him.

Here again we see discrepancy between Shannon's answer here and factual evidence. Namely, Shannon admits that he read Wiener's 1942 yellow peril report, which contains entropy/information precursory ideas, 'with interest', and we also know that in 1947 Shannon was sent a copy Wiener's 1946 special conference session 'Teleological Mechanisms' keynote address, which contains, nearly verbatim, in regards to entropy, information, message, and base two logarithms, what Shannon would eventually pen out the following year in his famous 1948 article, and we also know that in 1948 both Shannon and Weiner exchanged letters to each other in regards to their mutual use of the name entropy, albeit differing in sign, in their respective publications of that year. To continue:

> **OMNI:** Do you agree with Norbert Wiener, who is reported to have denied any basic distinction between life and non-life, man and machine?
> **Shannon:** That's a loaded question! Let me say this. I am an atheist to begin with. I believe in evolution theory and that we are basically machines, but a very complex type.
>
> **OMNI:** Does your theory give a hint of how life might have evolved, seemingly in the face of the second law of thermodynamics, which says that order should slowly disintegrate?
> **Shannon:** The evolution of the universe is certainly a puzzling thing to me as well as to everybody else. It's fantastic we've ever come to the level of organization we have, starting from a big bang. Nonetheless, I believe in the big bang.

In the last question, the interviewer probes Shannon on his thermodynamics opinion about the famous second law (disordering) versus evolution (ordering) seeming paradox, about which Shannon, like every other entropy-related interview query, completely evades, in regards to his knowledge about physical nature of entropy and thermodynamics—a clear indication that he seems to have lost the battle—that is to say, whatever it was that he was battling within himself for bring entropy and thermodynamics into the discussion in the first place, four decades earlier?

In June of 1956, to continue, Wiener, in response to Shannon's bandwagon article, published his own similarly-themed one page memorandum entitled 'What is Information', the gist of which is the following opening plea:[89]

> "Information theory has been identified in the public mind to denote the theory of information by bits, as developed by Claude Shannon and myself. This notion is certainly important and has proved profitable as a standpoint at least, although as Shannon suggest in his editorial, 'The Bandwagon', the concept as taken from this point of view is **beginning to suffer** from the **indiscriminate way** in which it has been taken as a solution of all informational problems, **a sort of magic key.** I am pleading in this editorial that information theory go back of its slogans and return to the point of view from which it originated: that of the general statistical concept of communication."

Wiener, however, goes on, in his article, to further convolute the issue by stating that his conception of a message—as a sequence of occurrences distributed in time as an *ensemble* (another term procured from statistical mechanics) of similar sequences—is 'closely allied to the ideas of Willard Gibbs in statistical mechanics'. This, again, is a huge misrepresentation; which is but Wiener's effort to parlay his cybernetics theory of animal feedback, using false connections to thermodynamics, as the solution to the second law versus evolution paradox. A string of binary digits (1s and 0s)—i.e. bits—in a message is not an *ensemble* of molecules. Wiener's cybernetics and thermodynamics ideas, however, as the Russian editor pointed out, have issues of their own, but that is a different story.[90]

In 1958, American electrical engineer and soon-to-be head of the MIT electrical engineer and computer science department Peter Elias published his mocking parody article 'Two Famous Articles', reprinted in full below, wherein he satirized the absurdity of Shannon-Wiener situation by reviewing two madeup fictional articles.[91]

Two Famous Papers

PETER ELIAS

September 1958

It is common in editorials to discuss matters of general policy and not specific research. But the two papers I would like to describe have been written so often, by so many different authors under so many different titles, that they have earned editorial consideration.

The first paper has the generic title "Information Theory, Photosynthesis and Religion" (title courtesy of D. A. Huffman), and is written by an engineer or physicist. **It discusses the surprisingly close relationship between the vocabulary and conceptual framework of information theory and that of psychology (or genetics, or linguistics, or psychiatry, or business organization).** It is pointed out that the concepts of structure, pattern, entropy, noise, transmitter, receiver, and code are (when properly interpreted) central to both. **Having placed the discipline of psychology for the first time on a sound scientific base,** the author modestly leaves the filling in of the outline to the psychologists. He has, of course, read up on the field in preparation for writing the paper, and has a firm grasp of the essentials, but **he has been anxious not to clutter his mind with such details as the state of knowledge in the field,** what the central problems are, how they are being attacked, et cetera, et cetera, et cetera.

There is a constructive alternative for the author of this paper. If he is willing to give up larceny for a life of honest toil, he can find a competent psychologist and spend several years at intensive mutual education, leading to productive joint research. But this has some disadvantages from his point of view. First, psychology would not be placed on a sound scientific base for several extra years. Second, he might find himself, as so many have, diverted from the broader questions, wasting his time on problems whose only merit is that they are vitally important, unsolved, and in need of interdisciplinary effort. In fact, he might spend so much time solving such problems that psychology never *would* be placed on a sound scientific base.

The second paper is typically called "The Optimum Linear Mean Square Filter for Separating Sinusoidally Modulated Triangular Signals from Randomly Sampled Stationary Gaussian Noise, with Applications to a Problem in Radar." The details vary from version to version, but the initial physical problem has as its major interest its obvious nonlinearity. **An effective discussion of this problem would require some really new thinking of a difficult sort, so the author quickly substitutes an unrelated linear problem which is more amenable to analysis.** He treats this irrelevant linear problem in a very general way, and by a triumph of analytical technique is able to present its solution, not quite in closed form, but as the solution to an integral equation whose kernal is the solution to another, bivariate integral equation. He notes that the problem is now in a form in which standard numerical analysis techniques, and one of the micromicrosecond computers which people are now beginning to discuss, can provide detailed answers to specific questions. Many authors might rest here (in fact many do), but ours wants real insight into the character of the results. By carefully taking limits and investigating asymptotic behavior he succeeds in showing that in a few very special cases (which include all those which have any conceivable application or offer any significant insight) the results of this analysis agree with the results of the Wiener-Lee-Zadeh-Raggazzini theory—the very results, indeed, which Wiener, Lee, Zadeh, and Raggazzini obtained years before.

These two papers have been written—and even published—often enough by now.

I suggest that we stop writing them, and release a large supply of manpower to work on the exciting and important problems which need investigation.

The first of these so-called two famous fictional articles he entitled 'Information Theory, Photosynthesis, and Religion', which pokes fun at examples of where Shannon's theory was being promulgated, misused, and abused. A representative modern example being a generic author—a prime example of which is German engineer and young earth creationist Werner Gitt (*In the Beginning Was Information*, 2006)—arguing that according to Shannon, entropy equals information; according to the second law, entropy tends to increase; according to nature, photosynthesis drives evolution; all in accordance with the divine words of Genesis 'let there be light'. This is the type of bandwagon silliness, which still goes on to this day, that Elias was poking fun at.

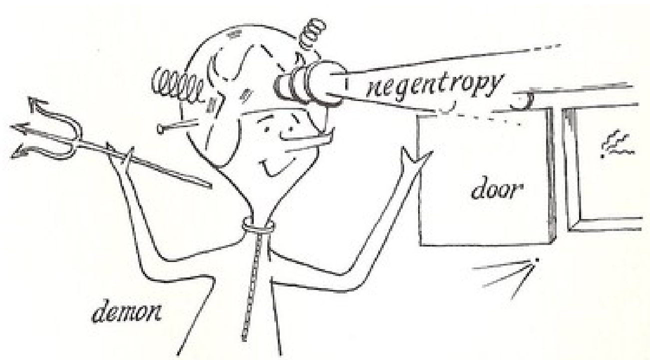
The second so-called famous (fictional) article, which Elias entitled 'The Optimum Linear Mean Square Filter for Separating Sinusoidally modulated Trianglular Signals from Randomly Sampled Stationary Gaussian Noise, with Applications to a Problem in Radar', is but an early-prototype example of what has recently become categorized, in modern science writing, as a 'Sokal affair', the result of a publishing hoax perpetrated by Alan Sokal, a physics professor at New York University, who in early 1996 submitted an science article entitled 'Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity', to *Social Text*, an academic journal of postmodern cultural studies, in which he proposed that quantum gravity is a social and linguistic construct—but then, on its date of publication (May 1996), revealed in the magazine *Lingua Franca* that the article was a hoax, identifying it as 'a pastiche of left-wing cant, fawning references, grandiose quotations, and outright nonsense, structured around the silliest quotations [by postmodernist academics] he could find about mathematics and physics.'[30]

This is essentially what Elias—who went on to become the head of the MIT electrical engineering department—is getting at: namely poking fun all the zealous information theorist's overly-verbose and sesquipedalian misuse of scientific terminology, along with a jab at the now-assumed notion that Wiener's usage of the term 'entropy', in his earlier 1942 cybernetics theory work on enemy aircraft detection, was now being convoluted together with Shannon's theory—radar detection theory and telegraph communication theory, to clarify, being two completely different subjects—to produce, in the words of Sokal, 'outright nonsense'.[30]

In 1972, Swiss theoretical physicist Josef Jauch and American mathematician Julius Baron, in their 'Entropy, Information and Szilard's Paradox' article, as discussed, give the following stern admonition:[13]

> "The fact that entropy can be applied to many fields is no excuse for confusing its different meanings when applied to physical systems or mathematical constructions. In particular, the identification of entropy of information (as defined by Shannon) as equivalent with negative thermodynamic entropy is **unfounded and a source of much confusion**. We have traced the origin of this confusion to Szilard. An analysis of Szilard's paradox, however, has shown specifically that [his] experiment is based on an inadmissible idealization; therefore it **cannot be used** for examining the principles of thermodynamics."

Jauch and Baron here correctly trace the ongoing linguist mess to the Szilard's 1922 article 'On the Decrease in Entropy in a Thermodynamic System by the Intervention of Intelligent Beings', an article in which Szilard—note note—*never* uses the term 'information' in his article—though, as mentioned, he does refer to an 'exactly informed' demon (which of course is good enough for information theorists), but rather is concerned with the nature of 'thermal fluctuations' (Brownian motion) in relation to the second law of thermodynamics and the Maxwell's demon argument, to initiate what has become known as a *Szilard demon* argument, depicted below:



A 1967 cartoon of a Szilard demon (information energy version of Maxwell demon) with a negentropy flashlight (with a power wattage of *k* ln *2* joules), from which the demon obtains 'information' about the movement and positions of the molecules in the room beyond the door.[92] French-born American physicist Leon Brillouin, in 1949, was the one who gave the argument that for the demon to identify the molecules, the demon would have to illuminate them in some way, i.e. shine negative entropy—or *negentropy*—as he came to say in 1950, on them, causing an increase in entropy that would more than compensate for any decrease in entropy such a being could effect.[93]

Szilard argued, in short, that the energy associated with the 'action' of measurement a system parameter, say a coordinate mapping the fluctuation parameter of the system, by a Maxwell's demon type intelligent being would, in the sensory-neurological system, involve a degradation or dissipation of energy, in the motor nervous system, whereby the quantitative entropy production measure, associated with this degradation/dissipation, involved in this neurological 'act', is, according to his estimates, *k* log 2 units of entropy, where *k* is Boltzmann's constant:[94]

$$k_B = \frac{R}{N_A}$$

which—to take STRONG note of—is in units of energy per unit degree not bits per symbol.. The original passage by Szilard that set all of this mess into play in the first place is the following:

> "We shall realize that the second law is not threatened as much by this entropy decrease as one would think, as soon as we see that the entropy decrease resulting from the intervention [of the demon] would be compensated completely in any event if the execution of such a measurement were, for instance, always accompanied by production of *k* log 2 units of entropy."

Nowhere, however, do the terms 'information' or 'information theory' enters into Szilard's famous discussion, but only become later adumbrations by agenda-fueled writers intent on bending over backwards to justify information theory in thermodynamical terms.

One example of bend-over-backwards writer is Russian-born American mathematician Anatol Rapoport, translator 1929 English edition of the Szilard article, who in his 1986 *General Systems Theory* comments on the Szilard paper that: 'this was the point of departure chosen by Szilard (1929), who laid the groundwork for establishing a conversion factor between physical entropy and information.'[95] Correctly, this is pure misrepresentation. Szilard did not establish a *conversion factor between physical entropy and information*, but rather only gave a crude proof that Brownian motion does not create a Maxwell demon type violation of the second law. That a hypothetical thermodynamic demon might have a 'sort of memory', with which to glean particle positions and trajectories, that generates a certain amount of joules per unit kelvin entropy, in the structure of the demon's mind when 'thinking', is a tenuous conjecture at best, and hardly a statement that Szilard made a connection between physical entropy, thermodynamics, and Boolean algebra, cryptography, and telegraph communications theory—and by far and wide hardly justification of the overly convoluted 2001 Haynie idea that cells gain binary digits of information and that the hypothetical Szilard demon mental entropy dissipation is a measure of this.

Heisenberg uncertainty principle

While Szilard did NOT establish a conversion fact between information theory and thermodynamics, he was a personal friend of Neumann—in 1930, for example, they taught a theoretical physics seminar together with Austrian physicist Erwin Schrodinger—and in the years to follow the publication of the Szilard demon article, the two of them, Neumann and Szilard, entered into discussions on the nature of the measuring process, in regards to Maxwell's demon and the newly forming uncertainty relation views emerging in the new field of quantum mechanics (Heisenberg uncertainty relation, 1927), and by the time of the publication of his 1932 book *Mathematical Foundations of Quantum Mechanics*, Neumann was citing Szilard's demon article, and discussing the repercussions of this in regards to the quantum nature of electrons, photons, and protons.

In short, the effect that the new quantum mechanical uncertainty view had in context entropy, is that the usual Gibbs-Boltzmann probability distributions p_i became replaced, in Neumann's formulation, by density operators ρ, or density matrix operators:

$$S = -k\mathrm{Tr}(\rho \ln \rho)$$

where k is the Boltzmann constant, Tr denotes the trace, the density operators being represented by matrices in the Hilbert space associated with the considered system. This so-called Neumann entropy formulation is the seen as the measure of uncertainty—of the Heisenberg uncertainty variety—associated with the description by ρ of the state of the system.[229] Here we see our first connection between *entropy* and *uncertainty*—which as we recall is a term usage that Shannon in his 1948 paper would vacillate on, namely his comment about the '**uncertainty** (or **entropy**) of a joint event.'[45]

In addition, by 1937, Neumann was being invited by Norbert Wiener to attend his developing lectures on his soon-to-be entropy-cybernetics theories, which further opened the lines of communication about Szilard's work and the newly-forming field of communication theory. Hence, with this mindset in place, it seems to have been the case that from Szilard's 1922 notions, about 'demon memory', energy dissipation, and his tentative assertion the 'execution of such a [memory] measurement [is] always accompanied by production of k log 2 units of entropy', that Neumann let out the joke comment to Shannon in their infamous 1940 naming choice conversation, when both Shannon and Neumann were co-workers at the Princeton's Institute for Advanced Study, that he should call his new logarithm of probabilities formulation by the name 'entropy' because, as recounted by Shannon in 1961, as told to Tribus, the 'same function appears in statistical mechanics', namely in the works of both Neumann (1932) and Szilard (1922).

Moreover, not only were the terms entropy and the Heisenberg uncertainty principle ping pong ball topics in the conversations of Neumann and Szilard, and hence by repercussion Shannon, while in the orbit of Neumann during his 1940 to 1941 Institute for Advanced Study postdoctoral stay, but in addition when Shannon arrived at the Institute he went to see his advisor German mathematician Herman Weyl telling him that he wanted to work on problems related to the transmission of information.[96] Weyl showed interest in Shannon's ideas, and soon they were discussing *analogies* between the transmission of information and the Heisenberg uncertainty relation.[97] The way this Heisenberg-influence filtered into Shannon's H theorem naming etymology, as Brazilian electrical engineer Erico Guizzo interestingly points out, is switching of section header titles, between the 1945 version and the change in the 1948 version, wherein his H theorem (Shannon entropy) is introduced, as shown comparatively below:[15]

	Article	Section
1945	"A Mathematical Theory of Cryptography"	Choice, **Information** and Uncertainty
1948	"A Mathematical Theory of Information"	Choice, Uncertainty and **Entropy**

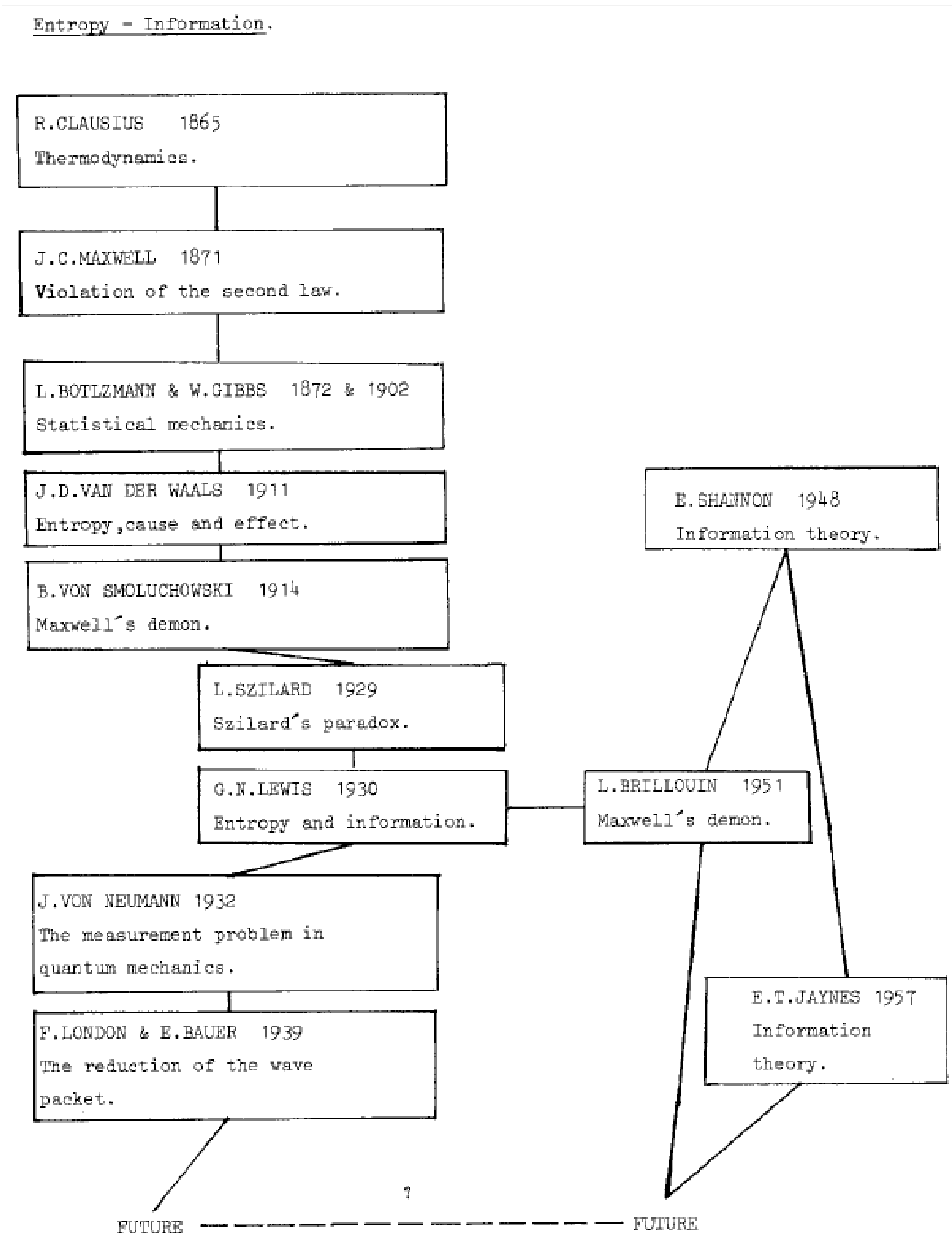
In short, as Guizzo clarifies, Shannon, in 1945, regarded his logarithmic H formula as a measure of *uncertainty*—not entropy.[15] It would thus seem to be the case at this point, 1945, that Shannon, in his search for a new logarithm equation namesake, was conceptualizing the act of choosing (choice) between a high (1) or low (0), or between two symbols, as being largely dependent, in some way, on the newly proposed 1927 quantum mechanical 'uncertainty' argument introduced by German theoretical physicist Werner Heisenberg, which states that it is impossible to simultaneously measure both the position and the momentum of a particle; or in equation form:

$$\Delta x \, \Delta p \gtrsim h$$

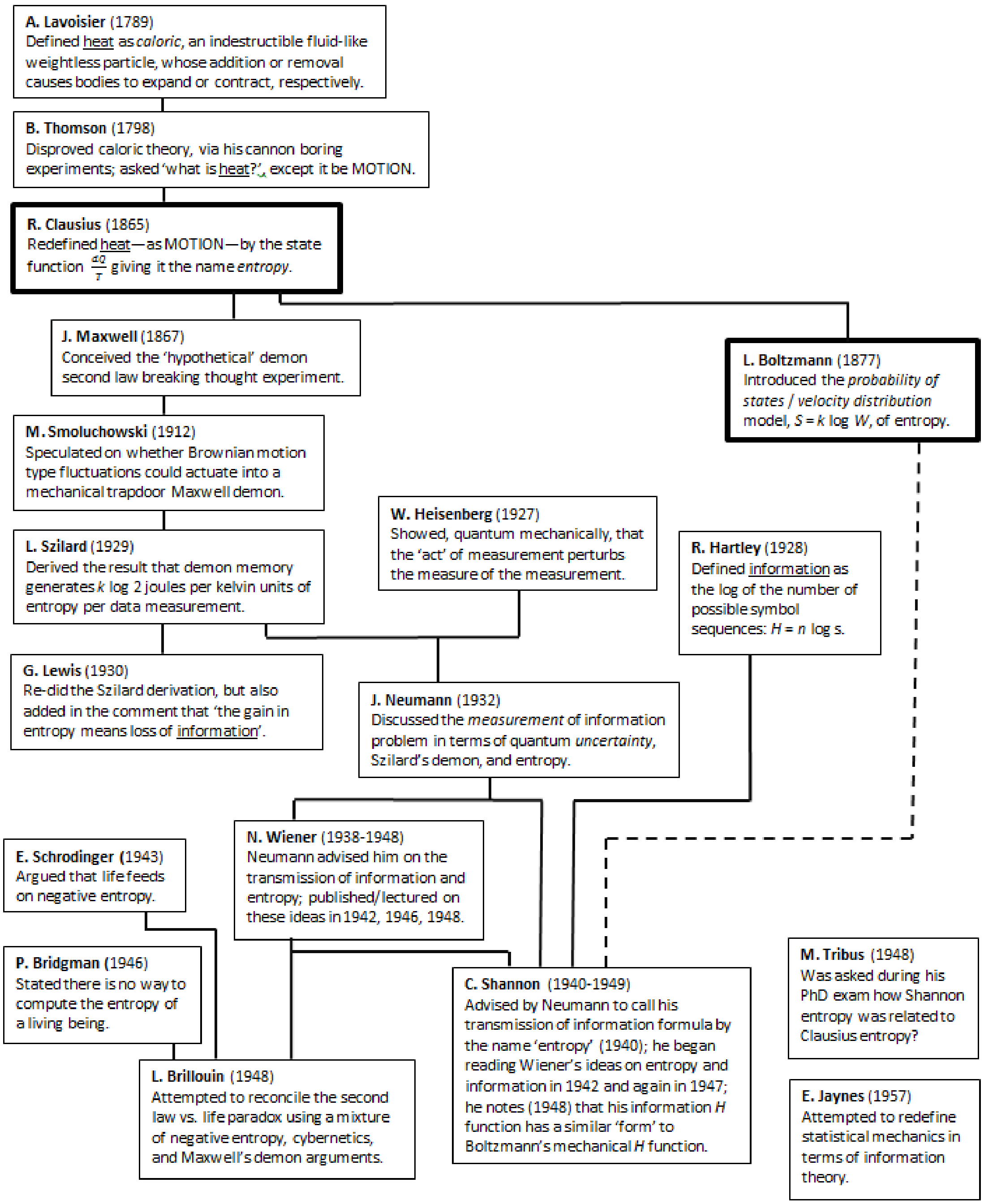
which states that the product of the variation in position Δx and the variation in momentum Δp of a particle will be greater than or equal to Planck's constant h.[98] If, in this sense, Shannon would have *chosen*—no pun intended—to stay with the name *uncertainty* (instead of *entropy*), for his logarithmic formula, this article—and the plethora of memorandum warnings—would never have had to been written.

This, however, has not been the case and in the decades to follow, entropy, Maxwell's demon, Szilard's demon (neurological memory processing), the Heisenberg uncertainty relation, quantum mechanics, and particle physics were all being convoluted together to crudely assert the punch line conclusion that: *information equals entropy*, or its negative, depending. This is exemplified in the following 1956 footnote by French-born American physicist Leon Brillouin wherein he comments: 'Neumann also considers the case of the observer forgetting the information, and states that this process also means an increase of entropy', citing Neumann's 1932 book.[99]

At this point it might be well intuitive to summarize the historical timeline of the so-called Szilard-origin of information theory, diagrammatically, which Swiss theoretical physicist Josef Jauch and American mathematician Julius Baron, in their 1972 article, attempted, for the first time, to analyze: 'the origin of the confusion is traced to a seemingly paradoxical thought experiment of Szilard', as they abstract things.[111] In 1975, building on Baron and Jauch's analysis, Swedish theoretical physicist Bo-Sture Skagerstam, in his article 'On the Notions of Entropy and Information', made a rather decent first-draft entropy and information theory connections flowchart, reproduced below:[112]



Here we see the state of things in the mind of someone in 1975 who believes and actively searches for theoretically possible 'deep' connections, as Skagerstam puts it, between Shannon (information theory) and Clausius (thermodynamics). The following is more accurate, updated, and strong tie/weak tie influenced entropy and information theory flowchart:



Skagerstam chart, to note, seems to be based on Leon Brillouin's 1956 historical survey.[145] Here we amend a few points of error. Firstly, Brillouin didn't originally cull his information-entropy ideas from Shannon, but rather from Wiener. Secondly, mention of Dutch physical chemist Johannes van der Waals

(1911) seems to nearly non-relevant, his dispersion forces are mentioned by Brillouin in regards to hypothetical demon senses, but in passing. Thirdly, mentions of German physical chemist Fritz London and French physicist Edmond Bauer (1939), on collapse of the wave function and consciousness, do not seem to be directly relevant, Neumann's interest in this aside, to the historical etymology of the manner in which 'information' came to be allegedly associated with 'entropy', but rather seem to be later adumbrations made by theorizers seeking to discern the quantum mechanical nature of information and or information theory. Lastly, American physicist Edwin Jaynes, and through later connection to him Myron Tribus, are what we might calls *second generation* information theory + thermodynamics connection seekers.

In regards to Jaynes, of note, when in 1958 American engineering student Zyssimo Typaldos told Tribus, the person who for ten years had been fretting about whether or not Clausius was related to Shannon, 'Oh, that's already been solved', regarding the apocryphal connection between Clausius entropy and the name-borrowed entropy of Shannon, pointing Tribus to Jaynes' two-part 1957 paper 'Information Theory and Statistical Thermodynamics', in which Jaynes attempts to derive a statistical thermodynamics interpretation of information theory, Tribus immediately obtained a copy the next day, commenting in retrospect about this Jaynes paper as though it were the holy grail:[113]

> "Here was my Rosetta Stone! I went home and worked with that paper for a week, almost without sleep. All of my studies for a decade suddenly fell in place. A straight forward connection between Shannon's entropy and the entropy of Clausius poured into the paper, almost without my hand."

Stepping ahead in time some 35-plus years, although people presently still search *in vain* for 'deep' connections, between Clausius and Shannon, Skagerstam's hypothesized future Shannon-Clausius dotted line connection has not materialized—and any and all discussions of a possible connection have ended in bitter failure and ridicule—the reason being that, as American anthropological neuroscientist Terrence Deacon puts it, in the long run 'the analogy to thermodynamic entropy breaks down.'[220]

One comment we might add, in regards to the position of Neumann in the embedded structure of the above flow chart, as he seems to be in large part the main facilitative player in bringing about the usage of the namesake 'entropy' in the transmission of information theories of both Wiener and Shannon, and through them Brillouin, Tribus, Jaynes and the others, is that according to science historian Steve Heims, from his 1980 book *John von Neumann and Norbert Wiener*:[150]

> "Neumann had appreciated the connection between entropy and information even before Wiener made it central to cybernetics and was peeved at the credit that fell to Wiener for exploring that connection."

Heims book, however, to put this statement in perspective, was aimed at putting Wiener use of science in a good spotlight and Neumann's use of science in a bad spotlight. Wiener, in any event, in his 1948 *Cybernetics*, specifically cites 'discussions with Neumann' as being the backbone or basis of his entropy and information formula, so the discussion is moot either way.[141] To get some insight into Neumann's mind at this point, the following is an excerpt from his 1949 *Physics Today* review of *Cybernetics*:[151]

> "The author is of the proposition that science, as well as technology, will in the near and in the farther future increasingly torn from the problems of intensity, substance and energy to problems of structure, organization, information, and control. The books leading theme is the role of feedback mechanisms in purposive and control functions. The reviewer is inclined to take exceptions to the mathematical discussion of certain forms of randomness in the third chapter [Time Series, Information, and Communication] of the book. The technically well-equipped reader is advised to consult at this point some additional literature, primarily L. Szilard's work. There is reason to believe that the general degeneration laws, which hold when entropy is used as a measure of the hierarchic position of energy, have valid analogs when entropy is used a measure of information. On this basis one may suspect the existence of connections between thermodynamics and the new extensions of logics."

Here we see firstly Neumann pointing out the delusional view that, in his day as is the case presently, some are coming to envisage information is the new theory of everything outranking physical science itself; secondly, that he objects, in some way, to the mathematics of randomness in Wiener's entropy and information chapter, which is curious; and thirdly Neumann stating his belief that the second law and entropy, as defined by Szilard's 1922 demon derivation, might have some future analog connection with information. Yet, to keep things in perspective, we also note that prior to this in Neumann's 1934 review of French physicist and economist Georges Guillaume's 1932 PhD dissertation turned book *On the Fundamentals of the Economy with Rational Forecasting Techniques*, wherein thermodynamics models are utilized, Neumann gives the following opinion about entropy:[152]

> "It seems to me, that if this [economic-thermodynamic] analogy can be worked out at all, the analogon of 'entropy' must be sought in the direction of 'liquidity'. To be more specific: if the analogon of 'energy' is 'value' of the estate of an economical subject, then analogon of its thermodynamic 'free energy' should be its 'cash value'."

Neumann, in short, envisions entropy 'analogons' in the form of both information and liquidity; hence we should absorb these so-called Neumann-based equivalences with a grain of prudent salt. Should we now, for instance, rename (market) *liquidity*, which is an asset's ability to be sold without causing a significant movement in the price and with minimum loss of value, as *entropy*, because 'Neumann says so'?

In 1977, to continue with memorandum warnings, Romanian-born American mathematician Nicholas Georgescu-Roegen, in his chapter 'The Measure of Information: a Critique', correctly traced the Shannon derivation back to the 1928 Hartley paper, as we have touched on herein, and gave his pungent views on the Shannon bandwagon effect as follows:[100]

> "A **muddled sematic metamorphosis** has led even to the identification of knowledge with low (negative) entropy. But Shannon, at least, showed his scholarly stature by denouncing in his 1956 article, 'The Bandwagon' the absurdity of the trend that has 'ballooned to an importance beyond the actual accomplishments'. Not surprisingly, however, **the parade with the naked emperor still marches on**."

The parade (1977) with the naked emperor still marches on indeed, the information theory balloon (1956) still floats, the melting pot (2011) still bubbles, and the bandwagon (2013) still rolls on. When, if ever, will the on-going naked emperor silliness end? Georgescu-Roegen, towards the end of his attack, concludes:

> "The bare truth is that **one does *not* meet the concept of physical entropy in communication theory**."

Georgescu-Roegen's attack here on Shannon's misunderstanding of thermodynamic entropy, however, to note, is a situation of the pot calling the kettle black, being that Georgescu-Roegen's own concept of 'material entropy' (*The Entropy Law and the Economic Process*, 1971), wherein, as he believes, crudely, that free energy = coal and bound energy = smog, in short, has created its own baseless bandwagon of its own in economics, ecology, and ecological economics, but that is a different story; the books: *Ecology and Management of World' Savanna* (1985), by J.C. Tothill and J.J. Mott, *Multi-Scale Integrated Analysis of Agroecosystems* (2003), by Mario Giampietro, and *Holistic Darwinism, Cybernetic, and the Bioeconomics of Evolution* (2005), by Peter Corning, are a few of many examples containing convoluted discussions of material entropy + Shannon entropy.[101]

In 1981, English chemical engineer and thermodynamicist Kenneth Denbigh gave his opinion about the Shannon bandwagon as follows:[102]

> "In my view **von Neumann did science a disservice!** There are, of course, good mathematical reasons why information theory and statistical mechanics both require functions having the same formal structure. They have a common origin in probability theory, and they also need to satisfy certain common requirements such as additivity. Yet, this formal similarity does not imply that the functions necessarily signify or represent the same concepts. The term 'entropy' had already been given a well-established physical meaning in thermodynamics, and it remains to be seen under what conditions, if any, thermodynamic entropy and information are mutually interconvertible."

Denbigh then followed this article up with an entire book, entitled *Entropy in Relation to Incomplete Knowledge* (1985), devoted to debasing the Shannon-based notion that entropy is a subject concept, e.g. that when two people observe the same physical system the one who has less information will assign to it greater entropy, and that entropy is an inverse measure of information.[153]

In 1982, Canadian zoologist Daniel Brooks and American systems ecologist Edward Wiley jumped on the Shannon bandwagon, blazing the torch of thermodynamics, and over the next six years attempted to ride the whole thing into Darwin's warm pond, wagon shown below.[103]

During the course of this bandwagon ride, Brooks and Wiley publishing a number of articles attempting to make a very tenuous connection between Shannon's entropy concept, genetics, cosmological entropy, and evolution, in the end resulting in their nearly inane 1996 book *Evolution as Entropy*, at which point—in regards to bandwagon memorandum history—the shit hit the fan, as one might say—or as Canadian self-defined physical information theorist John Collier softly put it, in his review of their book: 'Critics argued that they *abused* terminology from information theory and thermodynamics.'[104] Reading through the entirety of the Brooks-Wiley book is like having one's teeth pulled, albeit completely in the structural realm of one's intellect. This can be gleaned from the glaring oversight that in a book aiming to explain Darwinian evolution in terms of 'entropy' and the second law, the name 'Clausius', the formulator of the term entropy and formulator of the second law, is not to be found in the entire book. In any event, these types of oversights are common when one is happily speeding along in the bandwagon:

English animate systems thermodynamicist Harold Morowitz, in his derisive 1986 review article 'Entropy and Nonsense', critiques the use of Shannon-Boltzmann assumed entropy in the Brooks-Wiley bandwagon book, and essentially rips apart the growing nonsense of applying the blend of information theory + thermodynamics together to make platformed arguments in genetics and evolution. What is very humorous about this, is that in the quickly made rebuttal 1988 second edition of *Entropy and Evolution*, Brooks and Wiley are so perturbed Morowitz' derisive title: 'Entropy and Nonsense', that they remove the actual article title from the citation, giving it in the following form:

Original Title	**Retitled Title**
● Morowitz, H. J. (1986). "Entropy and Nonsense", *Biology and Philosophy*, 1:473-76.	● Morowitz, H. J. (1986). "Review of Brooks and Wiley 1986", *Biology and Philosophy*, 1:473-76.

Resultantly, it actually takes the reader some extra detective work to find Morowitz' article, being that "Review of Brooks and Wiley 1986" is not found in Google scholar.

Morowitz, being no amateur in the field, having published several books on entropy in cellular biology and energy flows in animate systems as well as having been an expert witness in the famous 1982 McLean vs. Arkansas Board of Education teaching creationism in public schools trial, on the question of whether or not the second law violates evolution, opens to the correct view that their book should be retiled as *Evolution as Entropy: an Extensive Thermodynamic State Variable*, rather than what the book thematically argues, which is essentially the title *Evolution as Entropy: Binary Digits of the Fictionalized Second Law Variety*. Morowitz then states, in excellent form:[105]

> "I begin with this linguistic nitpicking because it is important to realize that this book uses imprecise meanings and poor writing to cover up **fundamental nonsense** and emptiness of the underlying ideas."

Morowitz continues:

> "The only reason for reviewing such a work is that a number of biologists untrained in thermal physics and information science **have been fooled** into believing that there is some content in the 'Unified Theory' of Brooks and Wiley, and it is important to realize these biologists [have been] **mesmerized by the language** and equations of physics to support a [baseless] hypothesis [evolution is an information-entropic process]."

Morowitz then explains how the Shannon entropy namesake adoption has resulted in profound confusion, particularly for those unfamiliar with the underlying details of thermodynamics:

> "Since Shannon introduced the information measure in 1948 and showed an analogy between the information measure ($-\sum p_i \, ln_2 p_i$) and the entropy measure of statistical mechanics ($-k\sum f_i \, ln \quad f_i$), a number of works have appeared trying to relate 'entropy' to all sorts of academic disciplines. Many of **these theories involving *profound confusion*** about the underlying thermal physics to bolster otherwise trivial and vacuous theories."

Morowitz, in his 1993 book *Entropy and the Magic Flute*, although he side-steps the Shannon entropy-information confusion issue, touches on the statistical mechanical work of Boltzmann and Gibbs, and on the cover of his book gives us the following humorous depiction of the various ways in which entropy has become a pied piper concept, used and abused by many, over the years, particularly in information science:

which shows the crude idea—held loosely in the mind of many scientists—that entropy, symbol *S*, the exact differential state function formulation of heat conceived by Clausius in 1865 (middle equation), is the same as the Boltzmann-Planck 1901 formulation of entropy (first equation), which is the same as the Gibbs-Shannon 1902 statistical mechanics formulation of entropy (latter equation), which is the same as the Bekenstein-Hawking 1972 formulation of black hole entropy (spiral cloud), which is the same as

American physicist and black hole coiner John Wheeler's later ideas about whow black holes absorb bits of information thus increasing their entropy:[106]

$$S = k \ln W = \frac{dQ}{T} = -k \sum f_i \ln f_i$$

all of which are played to a sweet formulaic tune—possibly by Count Rumford (Benjamin Thompson): the first to disprove caloric theory via his 1798 mechanical theory of heat cannon boring experiments, which thus acted to later initiated entropy theory—that seems to captivate one and all into a delightful trance of scientific inquire that leads many down the incredulous path of wonder and intrigue. It is thus no surprise that many writers of today are led by the magical flute of Shannon down the publishing path of writer obscurity.

While each of these various entropy formulations, as depicted above, has a certain utility to them, each comes with certain fine print conditions according to which the given formulation finds reasonal applicability—this is what is called the fine print of thermodynamics, and more often than not, novice investigators fail to read the fine print. American applied mathematician, plasma physicist, and electrical engineer Harold Grad's 1961 'The Many Faces of Entropy' article gives insight into the details of this fine print issue—and also jabs at the need to upgrade terminology:[107]

> "One of the reasons for the **bewilderment** which is sometimes felt at an unheralded appearance of the term entropy is the superabundance of objects which bear this name. On the one hand, there is a large choice of macroscopic quauntities (functions of state variables) called entropy, on the other hand, a variety of microscopic quantities, similiarly named, associated with the logarithm of a probability or the mean value of the logarithm of a density. Each of these concepts is suited for a specific purpose."

In 1985, American evolutionary chemist Jeffrey Wicken penned his Shannon bandwagon reaction article 'Entropy and Information: Suggestions for Common Language', to combat the proliferation of Shannon information in evolution arguments, such as found in works of Brooks and Wiley and especially in the way off-the-rails 1972 book *Information Theory and the Living System* by American chemist and nucleic acid researcher Lila Gatlin, wherein he explains that:[8]

> "The [Shannon-Weaver] achievement [has led] to a **mistaken belief** of several scientists (e.g. Lila Gatlin, 1972; Hubert Yockey, 1977) that a true *generalization* of the entropy concept [has been achieved], freeing it from the particular disciplinary framework of thermodynamics."

Wicken digs into the essental nature of the confusion as follows:

> "In thermodynamics, the macrostate is what is empirically measureable; the microstate is a theoretcial construct. Microstates are not empircally measurable. It is in this sense that a microstate differs fundamentally form a 'message' in information theory."

In other words, what Wicken was finding, going on among evolutionary theorists, in the 1980s, was that they—just as Shannon had done—were confusing or rather confounding microstate description equations together with signal description equations, simply because they had the same 'symbolic isomorphism', as

Shannon put it, and were relying on the weight of authority: Claude Shannon, who in turn was relying on the weight of authority (John Neumann), which as they seemed to be unware of was but an inside Sokal affair joke, as Peter Elias mocked in his 1958 parody article 'Two Famous Articles'. Wicken contineues:

> "**There is no need** in information theory to enter the 'entropy means lack of information' arena, or even to talk about entropy."

Wicken ends his article with the following:

> "To conclude: **there is no *real* information relevant to thermodynamics** beyond that proved by the macroscopic state specification. Entropy is real in thermodynamics. And whereas microstates are probably real in some more-than-accounting sense, the concept of 'microscopic information' concerning their *occupancy* at any moment ins an encumberin abstraction for thermodynamics. With information theory, on the other hand, entropy is the encumbering abstaction. Both abstractions are inimical to productive dialoge between thermodynamics and information theory."

In 1992, science writers Peter Coveny and Roger Highfield, in their 1992 *The Arrow of Time*, summarize the state of situation, over the previous five decades, as such:[108]

> "Information theory entropy and thermodynamic entropy **have repeatedly been confused** since the time of von Neumann."

In 1999, American organic chemistry Frank Lambert, in his *Journal of Chemical Education* article 'Shuffled Cards, Messy Desks, and Disorderly Dorm Rooms: Examples of Entropy Increase? Nonsense!', devotes a section to misappropriation of Shannon bandwagon in the minds, textbooks, lectures, and Internet pages of many competent chemistry and physics instructors:[109]

> "Another major source of confusion about entropy change as the result of the rearranging macro objects comes from information theory 'entropy'. Claude Shannon's 1948 paper began the era of quantification of information and in it he adopted the word 'entropy' to name the quantity that his equation defined. This occurred because a friend, the brilliant mathematician John von Neumann, told him 'call it entropy on one knows entropy really is, so in a debate you will always have the advantage'. **Wryly funny for the moment, Shannon's unwise acquiescence has produced enormous scientific confusion**."

Lambert continues:

> "Many instructors in chemistry have the impression that information 'entropy' is not only relevant to the calculations of thermodynamic entropy but may change them. **This is not true**."

This comment brings to mind Israeli physical chemist Arieh Ben-Naim (2008) and American physical chemist Daniel Graham (2011), discussed further below, who have actually produced books outlining a walk down this type of yellow brick road.[110] Lambert continues:

> "There is no invariant function corresponding to energy embedded in each of the hundreds of equations of information 'entropy' and thus no analog of temperature universally present in each of them. **The point is that information 'entropy'** in all of its myriad nonphysicochemical forms as a

> measure of information or abstract communication **has no relevance to the evaluation of thermodynamic entropy change**."

Lambert concludes:

> "Even those who are very competent chemists and physicists have become confused when they have melded or mixed information 'entropy' in their consideration of physical thermodynamic entropy. This is shown by the results in textbooks and by the lectures of professors found on the Internet."

Here, exemplified clearly, we see another reason why the modern Shannon bandwagon is so hard to derail: namely that in the minds of many hardened chemists, physicists, physical chemists, and engineers, belief in the vacuous notion that Shannon's *H* function is thermodynamical is so profound and ingrained—or as Julius Baron and Josef Jauch put it in 1972: 'the misleading use of the same name for mathematical and physical entropy is well-entrenched'—that questioning of this belief becomes an attack on one's mental integrity, and hence when ridicule of this false belief becomes public knowledge, a 'scientific warfare', in the famous words of English polymath Thomas Young, of sorts, results—and casualties are often a repercussion. This is one of the reasons for the use of over-kill in the present article. In the famous words of Max Planck:

> "A scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it."

In 2001, Japanese ecological thermodynamics economist Kozo Mayumi, building and expanding on his mentor Nicholas Georgescu-Roegen's previous 1977 Shannon bandwagon critique, devotes an entire chapter, entitled 'Information, Pseudo-Measures and Entropy', to outline a more rigorous mathematical discourse on the Szilard-Shannon-Brillouin illusionary notion that information equals negative entropy—at the end of which, Mayumi concludes:[114]

> "Having now followed the three principle scholars' work, regarded as responsible for the alleged equivalence between information and negative entropy, **it is now clear that this alleged equivalence is <u>physically baseless</u>**."

In 2002, Spanish mathematician Alberto Solana-Ortega, in his 'Homage to Claude Shannon' article, penned in the renewed interest in his work year following his 2001 passing (reaction end), comments the following in regards to Shannon's misfortunate entropy namesake adoption on the advice of Neumann:[158]

> "This [calling *H* entropy] created a situation of **enormous confusion** lasting up to date in many areas. The interpretation of this function as a measure of information motivated its rejection in several fields, because it had, apparently, nothing to do with the intuitive notion of information as a sematic concept. On the other hand, the name entropy led to an immediate and **unjustified identification** with thermodynamic entropy."

In 2007, German solid state physicist and thermodynamicist Ingo Müller, in his well-written and detailed *A History of Thermodynamics*, penned the following memorandum:[115]

> "No doubt Shannon and von Neumann thought that this was a funny joke, but it is not, it merely exposes Shannon and von Neumann as intellectual snobs. Indeed, it may sound philistine, but a scientist *must* be clear, as clear as he can be, and **avoid wanton obfuscation at all cost**. And if von Neumann had a problem with entropy, he had no right to compound that problem for others, students and teachers alike, by suggesting that entropy had anything to do with information."

Müller clarifies, in conclusion, that:

> "For level-headed physicists, entropy—or order and disorder—is nothing by itself. It has to be seen and discussed in conjunction with temperature and heat, and energy and work. And, if there is to be an extrapolation of entropy to a foreign field, it must be accompanied by the appropriate extrapolations of temperature, heat, and work."

In 2008, Israeli physical chemist Arieh Ben-Naim, in his booklet *A Farewell to Entropy: Statistical Thermodynamics based on Entropy*, in reference to the previous 1981 Denbigh review, states that:[116]

> "I agree with the first sentence by Denbigh and indeed: *In my view* ***von Neumann did science a disservice***."

Ben-Naim, however, is of a peculiar variety of rare physical chemists, who thinks that Shannon entropy should be renamed (see: rename table below), and is under the pied piper impression that the entire field of physical chemistry, in fact the entire SI unit system, the bedrock of science itself, can be reformulated into units of bits, e.g. by redefining the absolute temperature scale, throwing out Planck's constant, and making thermodynamic entropy unitless (Brillouin's idea), among other absurdities—which of course is a delusional view. Beyond this, Ben-Naim is so brainwashed—or rather does not see the light, as Planck put it— by the idea that thermodynamics needs to be reformulated in terms of information theory, that in regards to in giving his reason for why he agrees with Denbigh that Neumann did science a disservice, he states 'I would simply say that I shall go back to Clausius' choice of the term, and suggest that he should have not used the term entropy in the first place.' This is an example someone afflicted by Shannon syndrome.

In the 2008 book *Observed Brain Dynamics*, Americans theoretical physicist and neuroscientist Partha Mitra and scientific informatics analyst Bokil Hemant have been forced to append full reprints of both the Shannon 1956 bandwagon memorandum and the 1958 Elias bandwagon parody memorandum as appendixes to their book, owing to the growing misuse of the so-called Shannon-based information thermodynamic ideas in neuroscience articles. In the introductory pages to their book, they comment on this with the warning:[117]

> "**Superficial analogies** to engineering concepts are sometimes made without a proper demonstration of a good match between biological phenomenon in question and the engineering theory. The exhortations of Shannon and Peter Elias in a pair of famous editorials in the *Transactions on Information Theory* (reprinted in this volume) should be kept in mind. Therefore, **there is need for greater clarity and conceptual rigor** before engineering principles can be elevated to the rank of explanatory scientific theories in biology."

Terminology reform is what will help bring about greater clarity; there is no other way around it. The proliferation of the carry-forward effect of the Shannon-Boltzmann entropy confusion, as of 2009, is such that the name 'Shannon' now pops, periodically, up in online polls of the 'greatest thermodynamicist ever', whereas correctly Shannon was not a thermodynamicist, in any sense of the term, nor did he ever claim to be.[118]

In 2012, American cellular pathologist Sungchul Ji, in his *Molecular Theory of the Living Cell*, devotes an entire chapter section, entitled 'The Information-Entropy Relations', commenting that the supposed relation between *information* and *entropy* has been the focus of debates in recent decades, such as he has encountered in recent online forum discussions, and goes on to give a historical overview of various debate schools of thought positions fortified over the years, such as whether energy, entropy, negative entropy, and information are the same or different, pointing out the glaring fact of the unit issue, i.e. the 'units of energy (e.g. Kcal/mol) and information (e.g. bits) are different'. In the end, Ji concludes that:[119]

> "Information defined by Shannon and thermodynamic entropy are **not quantitatively related**. I recommend [that we] restrict the meaning of 'entropy' to its thermodynamic one as originally intended by Clausius and Boltzmann and remove the term 'entropy' from all discussions on information as defined by Shannon."

This is all very cogent. Ji, however, convolutes his recommendation by bring his own agenda into the argument, namely his 1991 theory that 'all self-organizing processes in the universe, including the evolution of life, are driven by *genergy* [a term he coined], the complementary union of *information* (gn-) and *energy* (-ergon)', which is an error ridden argument, not germane to the focus of the present article.[120] Energy and or entropy portmanteaus, to note, are very common; the author, online, has cataloged dozens of them.[230]

You stole my Maxwell's demon!

On a humorous aside endnote to this extended article, as of 17 Dec 2012, the author has recently become aware, via research into American anthropological neuroscientist Terrence Deacon's commentary on Seth Lloyd's misrepresentation of history and how the analogy to thermodynamic entropy breaks down, etc., as presented in his 2011 book *Incomplete Nature: How Mind Emerged From Matter*, wherein he attempts outline an upgrade alternative to Shannon information, in the context of thermodynamics, that Cuban-born American philosopher Alicia Juarrero, author of the 1999 book *Dynamics in Action: Intentional Behavior as a Complex System,* has initiated legal action with the University of California, Berkeley, claiming that Deacon stole or rather misappropriated her information theory based Maxwell's demon theory of emergent anti-reductionism. The entire affair is documented online at the recently-launched cites AliciaJuarreo.com (29 Mar 2012) and TheTerryDeaconAffair.com (27 May 2012), the gist of which has been summarized online by the author, in the *Hmolpedia* Terrence Deacon article, and is well quite entertaining, to say the least.[231] The author has stated his views on the matter to both Juarrero and Deacon, which seems to be the case of "they stole my theory" paranoia, but being that the issue is presently in confidentiality binding discussions, we will leave this issue alone for the time being.

In summary, then, of this history of warning memorandums, the adopted namesake 'entropy' used to describe strings of binary digits, sent as programmed voltage pulses, current pulses, or radio waves, by a telegraph operator or computer program, used and discussed in theories on the transmission of information, in telegraphy, telecommunications, data processing and storage, etc., has absolutely nothing to do with the namesake 'entropy', i.e. heat differentials, which act to cause a body to expand or contract, aka Boerhaave's law, used and discussed in the science of thermodynamics; the two having only *non-humorous*, as we have shown, namesake and residual mathematical isomorphism in common—the result of a frequently retold 1940 joke between thermodynamically-literate chemical engineer John Neumann and thermodynamically-illiterate electrical engineer Claude Shannon, that, in Neumann's satirical view, 'nobody knows what entropy is', hence one can proactively use the term 'entropy' in any argument, on any topic of discussion, to one's advantage.

The new engineer needs to be acutely aware of this fact, namley, because the growing use of so-called aleged information entropy is one of the 'weeds', using the aforementioned language of American science historian Erwin Hiebert, that has grown fervently in the 'garden of thermodynamics', and is beginning to choke out the growth of many newly growing flowers, fruits, and vegetables of applied thermodynamics, human thermodynamics in particular.[121]

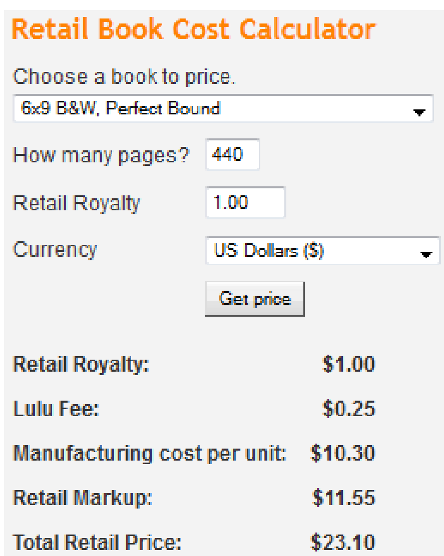
Wasted pages

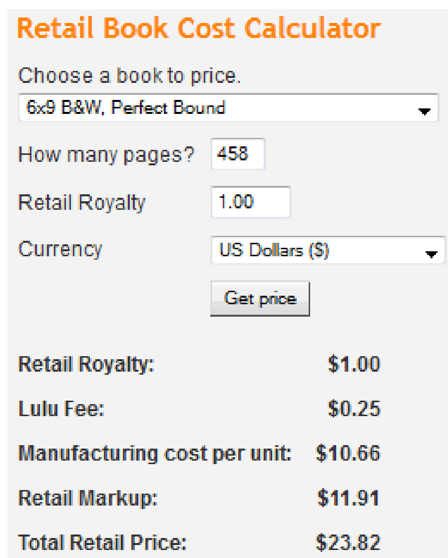
In stepping through the history of work devoted to dewheeling the Shannon bandwagon, one salient peculiarity noticed—particularly from the cost per printed book page point of view—is not only the amount time and energy wasted in this endeavor, or in the 1958 words of Peter Elias 'I suggest that we stop writing them, and release a large supply of manpower to work on the exciting and important problems which need investigation', but more importantly the amount of extra physical paper, per book or article, that must now routinely be devoted to a digression on why not to use Shannon information theory outside of communication engineering proper. The following gives a loose outline of books containing appended sections on warnings of the Shannon bandwagon effect:

Year	Book	Section
1971	*The Entropy Law and the Economic Process* (Nicholas Georgescu-Roegen)	§Appendix B: Ignorance, Information, and Entropy (pgs. 388-406).
1998	*The Way: an Ecological World-View* (Edward Goldsmith)	§Appendix Two: What is Information? (pgs. 449-58).
2001	*The Origins of Ecological Economics: The Bioeconomics of Georgescu-Roegen* (Kozo Mayumi)	§Chapter 4: Information, Pseudo-Measures and Entropy: an Elaboration on Georgescu-Roegen's Critique (pgs. 32-44).
2003	*From Complexity to Life: On the Emergence of Life and Meaning* (Niels Gregersen)	§:Appendix 7.1: Negentropy and Disinformation (pgs. 142-45)

2007	*A History of Thermodynamics* (Ingo Muller)	§Insert 4.8: Shannon's Information (pgs. 124-25).
2008	*Observed Brain Dynamics* (Partha Mitra and Bokil Hemant)	§Appendix A: *The Bandwagon* by C.E. Shannon (pgs. 343-44). §Appendix B: *Two Famous Papers* by Peter Elias (pgs. 345-46).

These few quick book appendices and or insert examples, of many—not to mention the writing of two full bandwagon derailing books: English physical chemist Kenneth Denbigh's 1985 *Entropy in Relation to Incomplete Knowledge* and American biochemist Jeffrey Wicken's 1987 *Evolution, Thermodynamics, and Information: Extending the Darwinian Program*—only touch on the surface of a bubbling issue surrounding the growing tension-ridden need to derail the Shannon Bandwagon and pop the information theory balloon. Playing around with the online LuLu.com book cost calculator, used by authors, gives a visceral idea of how much money is wasted by book consumers in paying for these extra pages. The cost to print Georgescu-Roegen's 18-page appendix, devoted to derailing the Shannon bandwagon in economics, in modern figures, for example, equates to an increase in cost of about $1 dollar wasted, per book:[122]





Beyond this, there already is enough garbage mucked theory to sift through in the field of economic thermodynamics, the majority of Georgescu-Roegen's material entropy theory being one example, ideal gas law economic isomorphisms being another, than to have to waste more time reading through an explanation by one garbage theorist as to why another garbage theorist's theory is garbage. In other words, a ride on the Shannon bandwagon is a waste of time, energy, and money, for all parties involved, not to mention that the music sounds horrible.

History of remaining initiatives

"The first thing needed is the rectification of names."
—Confucius, Analects 13:3

The can of worms has been opened—or as Myron Tribus overzealously put it the 'genie', who refuses to return to his bottle, 'has been unleashed'—this cannot be denied. The task that is before us now is to figure out a way to get the worms or genie, depending, back into their container or at least to figure out a way to make the genie's magical powers disappear. A very simply way to do this, as discussed, is via name modification. This section will outline a short history of renaming or name changing proposals, in regards to the notorious and career ruining, for some, term 'Shannon entropy', and conclude with proposed new 'magic word' to once and for all get the genie back in his lamp.

The Russian editor to the 1953 translation of Shannon's 'A Mathematical Theory of Communication', seems to have been the first to make a renaming effort, namely by, as mentioned, changing title to 'The Statistical Theory of Electrical Signal Transmission', and throughout the text substituted 'data' for 'information' and put the term 'entropy' in quotation marks, while at the same time distancing the use of the term 'entropy' in the text from its controversial discussions in physics and biology.[76]

In 1985, American evolutionary biochemist theorist Jeffrey Wicken, in his 'Entropy and Information: Suggestions for Common Language' article turned very popular 1987 book *Evolution, Thermodynamics, and Information: Extending the Darwinian Program*, made a commendable jab at name recommendations. He states specifically that the Shannon entropy name needs to go:[123]

> "As a result of independent lines of development in thermodynamics and communications theory there are in science today two 'entropies' **This is one too many**. It is not science's habit to affix the same name to different concepts. Shared names suggest shared meanings, and the connotative field of the old tends inevitably to intrude on the denotative terrain of the new."

The following table is a detailed listing of both the early etymological origins of Shannon's transmission of information logarithm function naming alternatives—intelligence, information, uncertainty, choice, and entropy—all used seemingly interchangeably during the years 1939 to 1948, along with more recent *name change* suggestions, proposals, and discussions:

Person	Shannon function etymology and name change suggestion timeline
Claude Shannon (1939)	Letter to American analog computer engineer Vannevar Bush at MIT: "On and off, I have been working on an analysis of some of the fundamental properties of general systems for the *transmission* of **intelligence**."[48]
Claude Shannon (1940)	"When I discovered my [*transmission* of intelligence] function, I was faced with the need to name it, for it occurred quite often in my theory. I first considered naming it **'information'** but felt that this word had an unfortunate popular interpretation that would interfere with my intended use in the new theory. I was then inclined towards the name **'uncertainty'** and [in Princeton] discussed the matter with John Neumann. He suggested that I call my function **'entropy'** because firstly the

	mathematical form of my function was already used in certain statistical thermodynamics treatises [e.g. Leo Szilard, 1929] and secondly, and most importantly, nobody really knows what entropy really is, so that if debate erupts I will always win. Shortly thereafter, I began to use the terms 'entropy' as a measure of 'uncertainty', using the two terms interchangeably in my writings."[3]
Claude Shannon (1948)	"The quantity *H*, which we shall call ***entropy***, in information theory, has a number of interesting properties which further substantiate it as a reasonable measure of **choice** or **information** (or information, choice, and **uncertainty**)."[45]
Harold Grad (1961)	"One of the reasons for the bewilderment which is sometimes felt at an unheralded appearance of the term *entropy* is the superabundance of objects which bear this name. The the **lack of imagination in terminology** is confusing."[107]
Fred Bookstein (1983)	Uses the term '**entropy-of-information**' in regards to the overlapping usage of the term entropy in the controversial 1982 Brooks-Wiley theory of evolution, which employs a melting pot mixture of information theory and thermodynamics.[125]
Stephen Kline (1997)	In his post-humorously published 1999 book *The Low-Down on Entropy and Interpretive Thermodynamics*, attempts to 'unravel the confusion', as he says, between Shannon-Brillouin use of the term entropy, and Clausius entropy, by using different symbols for each: "the last two quantities we have called entropy are *informational*: Shannon's entropy and Brillouin's entropy; **we will not use** the letter *S* for them as a first step in unraveling the confusions."[14]
Shu-Kun Lin (1999) Jan 28	After becoming confused (in 1996) about the overlapping usage both information entropy and thermodynamic entropy, in the field of molecular species classification and the Gibbs paradox of entropy of mixing, he launched the online *Entropy* journal as a forum to debated, discuss, and investigate 'whether the information-theoretic entropy and the thermodynamic entropy are compatible or not compatible', wherein he opens to following editorial guideline: 'there are many types of entropy reported in the scientific literature. The great diversity in the concept and definition may cause tremendous problems. My own humble suggestion is the following regarding the main two kinds of entropy: [68] 1. Any **information-theoretic entropy** (Shannon's entropy, *H*) should be defined in a way that its relation with information is clear. 2. Any theories regarding thermodynamic entropy (classical entropy, *S*, or the entropy of Clausius, Gibbs and Boltzmann and Plank) should conform with the second law of thermodynamics.' However, although he suggest we keep the terms in distinctly separate categories, he goes on to state that the *Entropy* journal will be an active forum to investigate 'whether there is any correlation between information-theoretic entropy and thermodynamic entropy', particularly in the fields of physics, chemistry, biology, economics, and philosophy; and also to discuss Prigogine entropy concepts.
Tom Schneider (1997)	In 1997, in his online article 'Information is Not Entropy!' gave the following name change suggestion:[21] "Shannon called his measure not only entropy but also **'uncertainty'**. I prefer this term."

	In 2006, the Wikipedia entropy article was citing Schneider as follows:[16] "The two terms, i.e. thermodynamic entropy and information entropy, often, in a rather confusing manner, have a supposed overlap due to a number of publications promoting this view. Many will argue that they are exactly the same, while others will argue that they have absolutely nothing to do with each other. Information entropy and thermodynamic entropy are closely related metrics, but are not the same metric. For most information theorists, this poses no difficulty, because their field is communication and computation using conventional electronic circuits where the thermodynamic meaning of entropy is not discussed. The conflicting terminology results in much confusion, however, in areas like molecular machines and physics of computation, where information and thermodynamic entropy are dealt with side by side. Some authors, like Tom Schneider, argue for dropping the word entropy for the H function of information theory and using Shannon's other term "**uncertainty**" instead."
Erico Guizzo (2003)	"Some think Shannon's quantity was **badly named**."[15]
Wikipedia (2003)	The 'Shannon entropy' article was created, but made as a redirect to the page: 'information entropy'; in 2008, a talk page proposal, with the header "**name change suggestion to alleviate confusion**", was posted, with following argument:[126] "I suggest **renaming** this article to either "Entropy (information theory)", or preferably, "Shannon entropy". The term "Information entropy" seems to be rarely used in a serious academic context, and I believe the term is redundant and unnecessarily confusing. Information *is* entropy in the context of Shannon's theory, and when it is necessary to disambiguate this type of information-theoretic entropy from other concepts such as thermodynamic entropy, topological entropy, Rényi entropy, Tsallis entropy, etc., "Shannon entropy" is the term almost universally used. For me, the term "information entropy" is too vague and could easily be interpreted to include such concepts as Rényi entropy and Tsallis entropy, and not just Shannon entropy (which this article exclusively discusses). Most if not all uses of the term "entropy" in some sense quantify the "information", diversity, dissipation, or "mixing up" that is present in a probability distribution, stochastic process, or the microstates of a physical system." Discussion and debate on this naming issue resulted in the page being renamed to 'Entropy (information theory)', which is the name of the article on Shannon's information theory H function as things currently stand (2012).
Arieh Ben-Naim (2008)	Made the nearly-backwards comment that: 'Clausius should not have used the term *entropy* in the first place [and that] Neumann should have suggested to the scientific community *replacing* [the term] entropy by information (or uncertainty or unlikely hood).'[116] This, to note, is what we might classify, medically, as: '<u>Shannon syndrome</u>', someone so deluded with the overzealous, albeit baseless, notion that entropy (in joules per kelvin) and the second law (the Clausius inequality) can be reinterpreted in information (in bits) and information theory (logs and probability arguments) terms, that he or she is willing to rewrite the entire course, structure,

	and foundation of scientific history, in their mind, all in the name of this pipe dream fueled vision; thinkers afflicted with Shannon syndrome tend to use near-mystical terms in their writings, such as: 'holy grail' (Gatlin, 1972), 'genie bottle' (Tribus, 1983), and 'Rosetta stone' (Tribus, 1998), among others, a residual effect of the euphoria; and tend to eschew equations.
Arieh Ben-Naim (2010)	Semi-jokingly suggests that Shannon's H-measure (Shannon entropy) should be renamed to **smomi**, a short for 'Shannon measure of missing information', which he says can be further abbreviated to **SMI**, concluding that 'with this [new] name, it will be clear once and for all who the real father of [Shannon's H-function measure] is.'[127]
Libb Thims (2011) May 2	In an email to Danish information theorist Peter Harremoes, the then editor-in-chief of the online *Entropy* journal, which is a proving ground for 'information theory + thermodynamics' type articles (though now more so the former than the latter), proposed the following: 'I would like to propose an information entropy name change special edition, similar to the way IUPAC has historically brought about agreement on terminology and unit consistency, e.g. SI units, on the proposal to change all non-thermodynamic formulations of entropy, i.e. Shannon-based, to a **new name** along with a clear explanation of the history and reasoning behind the switch. What was originally a joke made in passing between an aware John Neumann and unaware Claude Shannon has become the irritation and bugbear of the modern thermodynamicist and pied piper's tune and philosopher's stone to the non-thermodynamicist."
Peter Harremoes (2011) May 17	Reply to Thims (May 2): "Thank you for the proposal. First of all I agree with you about the issue that Shannon created by calling his quantity entropy. Obviously it is one of the purposes of the *Entropy* journal to push in the direction of clear notation and terminology. Some people use the terminology "relative entropy" to denote Kullback-Leibler divergence or information divergence as it is also called. I have systematically suppressed any use of the notion of relative entropy because it is even more confusing the normal notion of entropy, and there are much better alternatives. So what can we do about confusing use of the notion of entropy? We cannot ban the use of established terminology without proposing a good alternative. Actually alternatives exist. Some call it **self information** because it is the mutual information between a random variable and itself. In information theory it is sometimes called the **rate** as in rate distortion theory. Some call it **information** although this name may be ambiguous. I suggest that you write a "Letter" about this problem to *Entropy*."
Libb Thims (2011) Jun 3	Reply to Harremoes (May 17): "The proposal I have on my mind at the moment is to introduce the new term "**sientropy**", short for Shannon information entropy. I've mulled over alternative solutions, e.g. **itropy** (already used), **sentropy** (syntropy) (already used), as well as a complete new name proposal. Yet Shannon information entropy, and its variants, information entropy, information theory entropy, Shannon-Hartley information, etc., have such deep roots, that a complete uproot of the tree will be difficult. The newly proposed name "sientropy" is unused in the Internet and in Google Books, and would be proposed to refer specifically to Shannon's 1948/49 Nyquist-Hartley mathematical communication formulation for certain factors affecting telegraphy communication that quantifies 'information'."
Libb Thims	Email to American civil-ecological engineer Jeff Tuhtan: "I have been in

(2011) Jun 3	communication with Peter Harremoës, Editor-in-Chief of *Entropy*, with the proposal to do an information entropy name change special edition, with the aim to make recommended name assignments, similar to the way IUPAC (International Union for Pure and Applied Chemistry) organizes a unified naming system in the chemistry community. Harremoës suggests I send in a formal "Letter" to the journal. I'll memo this message to Harremoes, as well, to see if he would be interested in publishing a joint letter, from the both of us, along the lines of these proposals, as I know you have struggled with the Shannon-Boltzmann-Clausius issue of entropy in your dissertation work, as have countless others. Israeli physical chemist Arieh Ben-Naim's multi-book proposal that we reformulate the entire SI unit system, throwing out absolute temperature, remaking Planck's constant, etc., all to salvage Shannon information, measured in bits, is the signal that **it's time to address this issue**. A reading of sociologist Kenneth Bailey's 1990 *Social Entropy Theory* exemplifies where this terminology issue impacts the most, namely for the humanities students and professors, with no formal engineering or physics training whatsoever. Dozens of not hundreds of scholars, as mentioned in Bailey's book, have wasted entire careers being led down the piper's path to fool's gold ideas about binary digit variants of information having something to do with the steam engine, all justified by incorrigible suppositions, camouflaged by walls of inter-field barriers to elucidation, all framed in a mathematical web in great need of untanglement. Only when one is educated in both chemical engineering (Neumann), the home for Clausius-Boltzmann entropy, and electrical engineering (Shannon), the home for Shannon entropy, as my mindset is, can one clearly see the idiocy of this entire situation.
Sungchul Ji (2012)	Discusses his disagreements with Ben-Naim's views on terminology change, and in solution to what he calls the 'problem of the information-entropy paradox', he recommends that we 'restrict the meaning of 'entropy' to its thermodynamic one as originally intended by Clausius and *remove* the term 'entropy' from all discussions on information as defined by Shannon' and also, in case this suggestion does not work, gives a table, entitled 'a comparison between *entropy* and information', wherein he gives the alternative name: **intropy**, a portmanteau of 'informational entropy'.[128]
Libb Thims (2012) Nov 24	In updated late November 2012 thought-out retrospect, of the above outline—in particular Ji's 2012 suggestion (intropy) plus the author's earlier 2011 speculative term candidates (sientropy, itropy, sentropy, syntropy)—a relatively straightforward and simple naming change solution, to ongoing linguistic muddle, in regards to the falsified notion that 'information theory = thermodynamics', is the adoption of a completely new term: **'infotropy'** (in place of Shannon entropy), a conjunction or portmanteau of: Shannon **info**rmation + en**tropy**, which keeps the entire abrasive and debate ridden subject in quasi-connective historical context (in the sense of suffix *–tropy* being derived—through Clausius—from the Greek τροπή meaning to 'turn' or 'change', as in *transformation*, and the prefix *info*- being representative—through Shannon, of 'information', from the Latin *in-*, meaning 'into, in, or upon', and the suffix *-formare*, meaning 'to form, shape', which combined, as in *inform*, translates figuratively as 'train, instruct, educate', which essentially is what happens in the electromagnetic wave process of the *transmission* of information, in binary code, whether by radio or wire), yet disambiguates the two fields from future convolution. The new reversion coining *infotropy* is relatively an unused term in the

	literature and on the internet. The recent usage of the term *infotropy*, however, is found in the form of the title of the 2012 art gallery exhibit by American urban planner/sociologist turned fashion designer/artist Lat Naylor. A weakness of using the term 'infotropy', however, is that has a similar feel to the nearly inchoate field 'infodynamics' bandied about in the last decade by American zoologist Stanley Salthe, which creates a sense of repulsion to the term.[130]
Libb Thims (2012) Nov 25	In 24 Nov 2012 draft-version of the present article was sent to Tom Schneider to get his opinion on the above, about which after reviewing he was not favorable to the proposed term "infotropy", siding instead with his earlier "uncertainty" namesake usage for Shannon's H function, even after it was pointed out to Schneider that not only does Shannon's original 1948 definition of H as the "measure of information, choice, and uncertainty" then become recursive, but also the name "uncertainty function" confusingly conflicts the Heisenberg "uncertainty function", which often comes into the mix. Upon sleeping on this, the next day the term "**bit-tropy**" or "**bitropy**", short for "binary digit entropy" came into Thims' mind. Thims then emailed Schneider to get his opinion: "What do you think of term: "bit-tropy" or "bitropy", short for "binary digit entropy", as a name upgrade alternative for "Shannon entropy", which came to mind to me after sleeping on our conversation?"
Tom Schneider (2012) Nov 25	Schneider responded: Re: **'bitropy'**, "It doesn't help me. I suspect it wouldn't help a molecular biologist because they don't know what a bit is and they only have some sense of what entropy is."
Annick Lesne (2012) Nov 28	In email conversation with the author, in regards to a name change proposal to by the online *Entropy* journal and the name Shannon entropy itself, Lesne, author of the recent in-publication-process article "Shannon Entropy: a Rigorous Mathematical Notion at the Crossroads between Probability, Information Theory, Dynamic Systems and Statistical Physics", commented about the above: "Many thanks for sending me your article: there will never be enough papers underlining the differences between the various notions of entropy! I specifically like all the historical facts and quotations you are giving, which clarify a lot the matter. There is indeed **no direct link between information theory and thermodynamics**. The only link is indirect, through statistical mechanics and Boltzmann distribution, as presented e.g. in the papers by Balian or Georgii or in my more mathematically oriented review, based on (Shannon) entropy concentration theorems. Confusion even increases when considering the various maximum entropy or minimum entropy production or maximum entropy production principles!!! I don't know whether the editors of the journal *Entropy* will follow your recommendation! At least they should definitely

	rename their journal "*Entropies*"! A potential issue with the name bitropy is that people whose native language is close to Latin will understand the prefix as "bi" (i.e. two) instead of "bit". However, it is very difficult to change people's language habits, even if they are using wrong or misleading names, and I really don't know what is the easiest to adopt, between a smooth change (e.g. Shannon entropy, information entropy ...) or a new word like bitropy. What is definitely certain is that clarification is needed! Lesne here points out the fact that people might pronounce the newly proposed Shannon entropy name alterative as bi-tropy, hence not recognizing the 'bit' meaning of the term, which certainly is possible; but then again, as history has shown words with double a 'tt', as in *bittropy* (double t), tend to get truncated, i.e. remove the redundant letter, in the long. However, even if the prefix ***bi-*** does become interpreted as meaning 'two', instead of ***bit***, this is exactly what Shannon had in mind when in 1945 he was referring to 0 and 1, or rather the 'choice' between the **two** numbers in a logic gate or cable, as ***alternatives***—or what John Tukey the following year would come to call bits (binary digits); hence the term ***bitropy*** gives an even deeper etymological connection to what Shannon was digging at in his missing name for his new *H* equation, however one interprets the name upgrade. The proposed naming suggestion upgrade: '<u>bitropy</u>' (Shannon entropy) would thus translate, etymologically, as the transformation (-*tropy*, from the Greek *τροπή*, meaning 'turn' or 'change') of a choice between two (bi-) *alternative* (bits) into information (Boolean algebra).
Roman Frigg (2012) Dec 4	In review of this article and name change proposal, Frigg, co-author with Charlotte Werndl of the 2011 *Probabilities in Physics* chapter "Entropy: a Guide for the Perplexed", gave his opinion:[40] "I think I would not go as far as calling the terminological confusions surrounding 'entropy' a Sokal affair—so **a name change seems to be the right move**. But you are certainly right that the term has been overused, and in many cases stretched beyond breaking point. Many modern kinds of entropy have nothing, or at any rate little, to do with thermodynamics and so there is a good question about why they should bear the same name." Re: "Sokal affair", perhaps Frigg failed to take notice of Peter Elias' 1958 mocking parody editorial 'Two Famous Articles', reprinted herein (pg. 71), which specifically classifies Shannon information entropy as the 'original Sokal affair', before the concept of Sokal affair was even invented.
Jeff Tuhtan (2012) Dec 16	Comment: "Regarding using 'bitropy' and other suggestions for renaming Shannon's information entropy. Bitropy may be problematic as a general term if the message system used is not binary. As far as I know the Shannon entropy formulation is independent of the choice of base. Going back to Greek, I would suggest either '**logotropy**' (logos=thought, word) or '**grammotropy**' (gramm=writing, letter)."

Work that needs to be done

If this newly-proposed name modification suggestion is to successfully implemented, this of course requires that researchers throughout the world follow in suit in the upgrade switch to the new name—the first step of which will require that the online journal *Entropy* be renamed to *Bitropy* or at the very least to *Entropies*, as Annick Lesne suggests—an act that will fortuitously, in the keen foresight of Peter Elias, result to 'release a large supply of man power to work on exciting and important problems.'

The following, to further exemplify the amount future work that will need to be done to bring about terminology reform, are currently-existing information theory categorized Wikipedia articles that have the namesake 'entropy', inspired by Shannon, all of which, however, having absolutely nothing to do with thermodynamics:[131]

- B-ary entropy
- Binary entropy function
- Conditional entropy
- Continuous entropy
- Cross entropy
- Differential entropy
- Entropy encoding
- Entropy estimation
- Entropy power inequality
- Entropy rate
- Entropic uncertainty
- Entropic vector
- Generalized entropy index
- Hartley entropy
- Information entropy
- Information theoretic entropy
- Joint entropy
- Joint quantum entropy
- Maximum-entropy Markov model
- Maximum entropy method
- Maximum entropy probability distribution
- Maximum entropy spectral estimation
- Min-entropy
- Principle of maximum entropy
- Relative entropy
- Rényi entropy
- Shannon entropy
- Weighted entropy

The continuing spread of all of this baseless thermodynamics-borrowed terminology, as things currently stand, creates a huge mess in the scientific community, not so much for so-called *information theorists* (Wikipedia lists seventy-seven of them), who aren't bothered with semantic muddling, as the issue doesn't infringe on their daily line of work, but rather in fields, such as evolution theory, where lines become crossed and hence blurred, wherein, in the words of American chemist and evolution theorist Jeffrey Wicken the problem becomes especially acute:[8]

> "It is in biology, where the information and the thermodynamic meet, where problems with a 'Shannon entropy' **become especially acute**."

And it is not just in evolution theory where the problem is especially acute: John Coleman, Jay Teachman, John Galton, and Kenneth Bailey (in sociology), Jerome Rothstein, Luciano Floridi, and Robert Doyle (in philosophy), Horton Johnson (in pathology), Olivier Beauregard (in psychology), Terry Bynum (in ethics), Stephen Coleman (in politics), Seda Bostanci (in urban planning), to name a few, the latter two, Coleman (1975) and Bostanci (2008), in particular, doing their PhDs in this arena of linguist muddling.[132]

Rhetorical heat and lukewarmness

Before leaving this discussion, to touch quickly on the way in which heat dQ and or entropy $\frac{dQ}{T}$ should correctly be interpreted in human-social-economic-evolutionary perspectives—as indeed herein we have plowed through mounds and decades of incorrect information theory based perspectives—shown below is American physicist turned information theorist Hubert Yockey's opening quote to his controversial book *Information Theory, Evolution, and the Origin of Life*, by Italian art of war and how to be a wise prince philosopher Niccolo Machiavelli:[133]

> "It must be considered that there is nothing more difficult to carry out nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all those who profit by the new order, and only lukewarm defenders in all those who would profit by the new order, this **lukewarmness** arising partly for fear of their adversaries, who have the laws in their favor; and partly from the incredulity of men, who do not truly believe in anything new until they have had actual experience of it."
>
> — Hubert Yockey (2005)

The *thermal wording*—a 2002 coining of American physiological psychologist Mark Blumberg, who did his PhD dissertation on temperature changes in rats during sexual behavior—here, i.e. "lukewarmness", and feel of is nearly identical to Canadian Zoologist Daniel Brooks' reflective comment on his quicksand three decade plus attempt to use information theory blended with thermodynamics to explain evolution:[134]

> "By 1982, the centenary of Darwin's death, Niles Eldredge and Steven J. Gould had catalyzed a loosely connected group of evolutionary biologists unhappy with the New Synthesis to unleash a cascade of criticisms and proposals. Emboldened by this display of the scientific community at its meritocratic best, Ed Wiley and I entered the fray. The day we finished proofreading *Evolution as Entropy* [1986], David Hull presciently warned us *the fun was over*. Soon, I received an envelope from a friend who had seen a manuscript on a colleague's desk. Such privileged material is rarely copied and forwarded. My friend wrote, "I think you and Ed should know what you're up against." The privately circulated manuscript was authored by three academics at the University of California-Berkeley. Ed and I were stunned by its vicious tone. Why the **rhetorical heat**?"
>
> — Daniel Brooks (2011)

which also uses thermal wording, i.e. "rhetorical heat"—which, by no strange coincidence, is nearly identical to American engineer Myron Tribus' reflection on the last 50-years at a failed attempt to reformulate thermodynamics in terms of information theory:[43]

> "After my book on thermodynamics [*Thermostatics and Thermodynamics: an Introduction to Energy, Information and States of Matter*, 1961] appeared I sat back and waited for a call from the Nobel Committee. They never wrote. But other people did write and it was not at all what I wanted to hear. My attempts at getting engineering professors to adopt the new way to look at thermodynamics was a completed failure. Not only that, but I was **attacked** as someone who had taken intellectual shortcuts."
>
> — Myron Tribus (1998)

Interestingly, here, in comparison, we see three war-battered individuals reflecting on the turmoil of a 30-year plus uphill "heated" battle, each the end result of taking a ride on the Shannon bandwagon, even after being told the ride was over (e.g. "fun was over", Brooks, c.1985)—very curious similarity indeed. This is where the 'real' research into heat—and or heat differentials divided by the absolute temperature of the boundary surface of the system—otherwise known as *entropy* ($\frac{dQ}{T}$)—lies. Not in discussions about bits.

To point us in the right direction, American social-economist Henry Carey, in his famous 1859 *The Principles of Social Science*, used the Berthelot-Thomsen principle as a basis to formulate a theory of 'social heat'.[135] In introducing the topic of social heat between reactive human molecules in society, according to a review by Austrian social economist Werner Stark, Carey states:[136]

> "In the inorganic world, every act of combination is an act of motion. So it is in the social one. If it is true that there is but one system of laws for the government of all matter, then those which govern the movements of the various inorganic bodies should be the same with those by which is regulated the motion of society; and that such is the case can readily be shown."

Then, in what seems to be a citation of Berthelot-Thomsen principle, that the 'heat of a reaction was the true measure of affinity', Carey states:

> "To motion there must be heat, and the greater the latter, the more rapid will be the former."

This means, according to the 1962 opinion of Stark that:

> "In the physical universe, heat is engendered by friction. Consequently the case must be the same in the social world. The 'particles' must rub together here, as they do there. The rubbing of the human molecules, which produces warmth, light and forward movement, is the interchange of goods, services, and ideas."

Carey continues:

> "In the material world, motion among atoms of matter is a consequence of physical heat. In the moral world, motion is a consequence of **social heat**—motion, consisting in an 'exchange of relations' resulting from the existence of those differences that develop social life. Motion is greatest in those communities in which agriculture, manufactures, and commerce are happily combined. That such is the fact will be obvious to all who see how rapid is the spread of ideas in those countries in which agriculture, manufactures, and commerce are combined, compared with that observed in those which are purely agricultural. In the one there is great heat and corresponding motion, and the more motion, the greater is the force. In the other there is little heat, but little motion, and very little force."

This is where the REAL research and debated into the nature of entropy in human affairs lies—in partial differential equation state function formulations of heat, work, and energy in human interactions—not in Claude Shannon's 1948 'A Mathematical Theory of Communication', which as Jeffrey Wicken so aptly explained is NOT a real entropy. Our skulls may be thick, but truth is a strong solvent.

Conclusion

In conclusion and summary, a good rule-of-thumb, that we can take away from this historical romp of silliness, is that if one cannot trace one's derivation back to a combination of both the caloric combustion theories of Lavoisier and the mathematical reciprocity relation laws of Euler, then one is not talking about entropy. Secondly, if one has the inclination to apply thermodynamics to some field in aims solving some particular problem, the methodology one should use is the following:

a. Read Clausius' *The Mechanical Theory of Heat*.
b. Think real hard.
c. Write down the solution.

which, of course, is but a first and second law based version of the famous Feynman problem solving algorithm.[137] Use or citation of Shannon—*outside* of communications engineering proper—is but a transformation into an Aunt Sally.

Last, but not lease, to use our newly-proposed Shannon entropy upgrade term replacement: *bitropy*, in a clarifying and mind-cleansing manner, the following what American cellular pathologist Sungchul Ji in 2012 described as the 'Bible test', which he uses in his work to help clarify the difference between information entropy (*bitropy*) and thermodynamic entropy (*entropy*):[128]

> "The historical information contained in the Bible is understood only by humans but not by nonhuman species and is furthermore temperature-independent. That is, raising the temperature of the Bible from room temperature by, say, 30° C would not change the biblical information [*bitropy*] content whereas the entropy [*thermodynamic entropy*] content of the book will increase. When one heats up a book such as the Bible, the *thermodynamic entropy* associated with the molecular motions of the paper constituting the pages of the Bible will increase but the informational entropy [*bitropy*] associated with the arrangement of letters in the Bible will not be affected until the temperature increases high enough to burn the Bible. This thought experiment may be conveniently referred to as the *Bible test*."

The Bible test, as Ji describes it here, to note, historically, has its precursor in French-born American physicist Leon Brillouin's 1949 'Life, Thermodynamics, and Cybernetics' article, wherein he asks what the difference between standard Clausius entropy and American mathematician Norbert Wiener's newly-formed 1946 conception of information as the negative of entropy in regards to printed text and a blank piece of paper:[142]

> "Take an issue of the *New York Times*, the book on *Cybernetics*, and an equal weight of scrap paper. Do they have the same entropy? According to the usual physical definition, the answer is 'yes'. But for an intelligent reader, the amount of information contained in these three bunches of paper is very different. If 'information means negative entropy', as suggested by Wiener, how are we going to measure this new contribution to entropy?"

Brillouin here, to clarify, misinterprets Wiener. Namely, Wiener was *not* concerned with the amount of information in printed form, but rather with the 'information' contained in a message, whether through telephone lines or in a nerve connection, according to which, in his view, 'entropy', which he considered as the measure of randomness or disorganization, of the second law variety, is the 'negative of the amount of information contained in the message—thus, essentially, the amount of information is the negative of information', as he told the New York Academy of Sciences in 1946 during a special conference session on 'Teleological Mechanisms', these outlines resulting in his 1948 *Cybernetics* book.[73] Hence, naturally enough, Brillouin misinterprets Wiener's use of the term information above—as is the case in nearly all extracurricular information theory extrapolations, outside of communications engineering proper, as we have covered extensively herein.[73]

Quotes

> "**Information is information**, not matter or energy."
> — Norbert Weiner (1948), *Cybernetics* [141]

> "Shannon's theory is **inapplicable** to the world of living things."
> — Edward Goldsmith (1998), *The Way: an Ecological World-View*[204]

> "Von Neumann was certainly correct in anticipating that conflating information and entropy would result in mass confusion; Shannon's information concept has to be one of the **most misunderstood notions on the planet**, perhaps second only to the theory of relativity or the 'laws' of supply and demand."
> — Philip Mirowski (2001), *Machine Dreams* [52]

> "From a physical point of view, information theory has **nothing to do with physics**."
> — Daniel Ueltschi (c.2011), 'Shannon Entropy'[173]

Notes

N1. (a): the subtitle of this article 'Science's Greatest Sokal Affair' was chosen prior to finding out that Shannon's information theory already once had its own Saturday Night Live style Sokal affair parody article entitled "Two Famous Papers" done by MIT electrical engineering head Peter Elias in the 1958.
(b): preliminaries of this article were discussed in series of May 2011 email-exchanges with Danish information theory mathematician Peter Harremoes, the, at-the-time, editor-in-chief of the online *Entropy* journal, wherein Thims proposed a name change special edition, similar to the way in which IUPAC historically has brought about terminology consistency and unit agreement among chemists world-wide.
(c): some of the material of this article appeared previously in an April 2012 human thermodynamics chapter handout to students of a bioengineering thermodynamics class, as required reading material prior to an overview lecture on human thermodynamics by the author.
(d) eoht.info/page/Libb+Thims+%28lectures%29

(e) Thims, Libb. (2012). "Human Thermodynamics: Chemical, Physical, and Engineering" (§14.1: Information Theory), Bioengineering Thermodynamics; pre-lecture required reading; tentative draft chapter 14 submission (by request of Merle C. Potter) for *Schaum's Outlines of Thermodynamics for Engineers, Third Edition*, by Merle C. Potter and Craig W. Somerton. McGraw-Hill.
(f) http://www.humanthermodynamics.com/HT_lecture__2012_.pdf

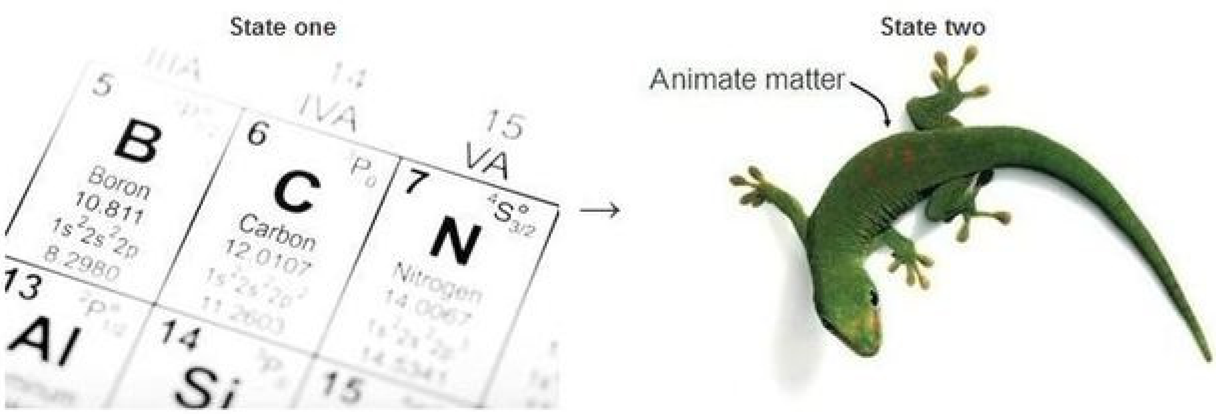
N2. The title of the present article "Thermodynamics ≠ Information Theory", in reflection, might well be classified as the antithesis of French-born American physicist Leon Brillouin's 1950 article "Thermodynamics and Information Theory", the argument of which is based on his previous 1949 article "Life, Thermodynamics, and Cybernetics", which is based on American mathematician Norbert Wiener's 1948 *Cybernetics* discussion of the notion that "information represents negative entropy", which—similar to the Shannon entropy etymology—is footnoted as being the result of a personal communication with John Neumann, who in turn culled his information-entropy relations from his close friend Hungarian physicist Leo Szilard, as presented in his 1922 "On the Decrease in Entropy in a Thermodynamic System by the Intervention of Intelligent Beings", a Brownian motion digression on the Maxwell's demon, which is based on Austrian-born Polish physicist Marian Smoluchowski's 1912 lecture "Experimentally Verifiable Molecular Phenomena that Contradicts Ordinary Thermodynamics", wherein he hesitantly presupposed that any demon must be a physical system subject to the second law, the demon of course the result of Scottish physicist James Maxwell's famous and viral 1867 hypothetical second law violating thought experiment, concerning a "very observant and neat-fingered being" able to trump the second law and bring about perpetual motion.[140]

N3. To clarify things for religiously minded readers—in regards to underlying implications of the use of the word 'Bible' and Biblical passages, Morse's famous 1844 telegraph message specifically, herein, as we know that a single religious mention in information theory discussions often has tendency to become promulgated into molded polemical platforms, the cult followers of Hubert Yockey, being one example—this author's Dawkins number is 10.[138] In words, the author is a 'hard core atheist', as Belgian philosopher David Bossens describes things in his 2012 book *Debates of the Hmolpedians*.[143] The author is a Goethean philosopher, and in regards to belief system, believes in the periodic table, the laws of thermodynamics, and that Shannon entropy has NOTHING to do with thermodynamics.[144]

N4. Regarding the use of the prefix "bio-" (Greek for *life*), herein, from a physical science perspective, 'there is NO thing endowed with life', as Serbian-born American electrical engineer Nikola Tesla put it in 1915.[206] This was verified by English physiologist Charles Sherrington in 1938 who concluded that the chemical-physics-thermodynamics-atomic perspective "deletes 'life' as a scientific category".[207] The author, as of 2009, has concurred with these views, chemical thermodynamically, concluding that **life** is indeed a **defunct scientific theory**.[208] Owing to cultural embeddedness, however, the ubiquitous prefix 'bio-' is retained in the present article in subtle usages including: *bio*medical, *bio*spheric, *bio*chemist, *bio*physical chemist, *bio*physical thermodynamicist, *bio*logical, *bio*physicist, *bio*grapher, *bio*economics, *bio*engineering, etc., in some 49 instances, or in the form of terms such as 'living things', e.g. Goldsmith's quote, above, about how 'Shannon's information theory is inapplicable to *living* things', France being the *birthplace* (of thermodynamics), etc. Terminology reform in this area is sorely needed; the author, however, not wishing to fight two battles on one front, is mute on this issue herein, this footnote aside. In lieu of bloating the already extended article with more term reform (in an article already devoted to term reform), we give the following endnote suggested usages for upgrade terminology—the latter group being dated term reform/alternative examples, the former group being more recent (2009-present) Hmolpedia-introduced term upgrades, presently being tested online in functional usage—many of the terms shown having individual hyperlinked pages:[208]

● Birth → Reaction start
● Life → Reaction existence
● Death → Reaction end
● Living → Animate (animate bound state existence)
● Alive → Reactive
● Biology → Chnopsology
● Living system → Chnopsological system
● Living matter → CHNOPS-based matter
● Died → Dereacted (Deboundstated)
● Dead → No reaction existence (Deboundstate existence)

● Living substance → CHNOPS+ elements (Edwin Hill, 1900; Anon, 1936)[213]
● Life → Animate matter (Alfred Ubbelohde, 1954)[214]
● Earth-based life forms → CHNOPS organisms (Harold Morowitz, 1968)[210]
● Biochemistry → The study of 'powered CHNOPS systems' (Henry Swan, 1974)[215]
● Life thermodynamics → Animate thermodynamics (Sture Nordholm, 1997)[216]
● Biogenic elements → CHNOPS (National Academy of Science, 1998)[211]
● The living perspective → The CHNOPS perspective (Paul Keddy, 2007)[212]



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