AETHEROMETRIC THEORY OF SYNCHRONICITY (AToS)

VOLUME VI

THE ELECTRODYNAMICS OF HEAT:

ENTROPY AND ORDER
IN THERMAL AND BIOLOGICAL SYSTEMS

CHAPTER 1:

"WHAT IS HEAT? "

By

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ABSTRACT

The present introductory monograph poses the general problem of understanding heat, its dynamics and how these are thought to obey a strange function and even stranger concept that goes by the name of entropy. It also casts a perspective on what is to come in our present disquisition on thermodynamics.

1. What is heat?

"It may be difficult, and it would certainly be rash, to venture to judge recent scientific work on the basis of history. But it is possible to discover in the history of heat and thermodynamics certain outstanding features which seem to be lacking in the modern scientific scene, and whose absence may represent a defect in our arrangements for science. Three key figures in our narrative - Carnot, Joule and Mayer - were in strict terms amateurs, or devotees, of science. They stood outside the 'establishments' of their days and because their ideas were unorthodox they were ignored. Carnot died unrecognized and Mayer was driven to despair, while Joule succeeded only through good fortune and very favorable personal circumstances. These men and the independent lines they took were essential for the progress of science. If we consider the strong and complex pressure which modern society exerts on all its members, scientists included, it is reasonable to wonder whether such men could work effectively today and, if not, whether science can continue to progress satisfactorily without them. Has it been shown that scientific 'establishments' are today more intelligent, more sensitive and more tolerant of unorthodox opinions than they were in the past? The lives of Carnot and Meyer remind us that our narrative has indeed included the elements of tragedy; it may be a greater tragedy if our society makes such careers impossible today."

Cardwell, D.S. (1989) "From Watt to Clausius - the rise of thermodynamics in the early industrial age"

1. 1. When is heat, heat?

That is a good question to which different answers have been given by those who profess to study heat and its dynamics for some three centuries. We are a long way from Sadi Carnot's notion that heat was a fluid, "caloric", that "fell" (by analogy to fluid mechanics) from a hot reservoir to a cold reservoir. Nowadays, some claim [1] that heat only exists in transit, as any amount of energy that spontaneously flows from "one body of matter to another" *due* to their temperature difference. Heat, as energy, would not have any other property or reality than that of a flow caused by a temperature difference, ΔT. This leaves one wondering whether the notion of a heat reservoir is simply a bad manner of speaking; or whether heat transfer can actually be made isothermally, at a constant temperature, as is supposed to happen in isothermal expansion or in the concept of "reversible heat". For if this is possible or admitted, then heat flow cannot be viewed as exclusively due to a temperature difference. Others [2] employ a wider definition that identifies heat with the energy of motion of the individual molecules of matter. If a container or a body holds a certain number of molecules at a given temperature, then their kinetic energy - whether translational, rotational or vibrational - constitutes the heat energy of that body. Then, we are perfectly entitled to speak of heat reservoirs. Each body of matter is one such thermal pile. But next, this, too, leaves one wondering as to whether all molecular motion present in a body of matter takes on the form of thermokinetic energy: how does the latter tally with molecular motion that is caused electrically? How do molecular thermokinetic and electrokinetic energy terms relate? Are they distinct forms of kinetic energy that may coexist in the same molecule? How does thermokinetic energy relate to the chemical bond energy of the molecules composing a body of matter? Are the two distinct - and how? And is the energy of chemical bonds the same as the bond enthalpy or enthalpy of a substance?

As distinct molecular concepts of thermal energy, both views leave plenty to be desired - and yet more questions to be made. Is heat not absorbed, retained and released when molecular states of matter change their phases? How is this heat of phase - often called *latent* heat of phase (e.g. of fusion, of sublimation, of vaporization) - reducible to a molecular state of motion? And the chemical energy stored in covalent bonds, how is it explained to consist of heat - how does it fall under the aegis of heat? Further, to top it all, is not electromagnetic field energy said to transmit heat - is not a microwave oven said to heat liquids and solids? How then do photons impart or transmit heat? Is there an electromagnetic heat that is distinct from the molecular thermokinetic heat?

To invoke the lame excuse - as some do - that energy is "difficult to define precisely" when its concept is sought on the basis of the laws of thermodynamics, only to then define it as "the capacity to provide heat", is a sheer cop-out; after all, if heat is energy in transfer (caused by a temperature difference, whose nullification by equilibrium, in turn, arrests that energy transfer), energy cannot be the capacity to provide heat... capacity is not a flow, but a reservoir, a potentiality. And if, conversely, heat is a kind of energy that can be stored in various ways (reservoirs, phase-states, chemical bonds), its flow, qua energy, cannot be solely caused by temperature differences.

If heat is so poorly defined, how can one trust the so-called science of thermodynamics - in all of its forms, classical (kinetic), stochastic or quantum-statistical? Einstein once quipped that classical thermodynamics was the only physical theory of universal import which he was convinced would never be overthrown:

> "A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Therefore the deep impression that classical thermodynamics made upon me. It is the physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic concepts." [3]

A few thermodynamic theories later, we are no closer to grasping the universal import of any of them when heat itself remains so poorly defined and circumscribed, when the most basic concept is so vague and imprecise. Einstein was wrong in many ways, and this is just one of them. Further, if one cannot adequately define heat, how is one not to misconceive the "heat capacity" of a given material, or the "internal energy of a system", or, still, the "entropy" of a thermal exchange?

It seems that, at the very least, one cannot properly speak of a science of thermodynamics - no matter what existing version of it one considers. In fact, thermodynamic engineering has remained largely an empirical discipline while the supposed science behind it merely forms a collection of fragmentary theories - most with a purely qualitative value, even when they enable computations that fit some data. It takes plenty of gall to pretend that thermodynamics forms a cohesive, universal science, when, at best, it can only be said to be in its infancy - and at worst, to be a collage of pseudo-scientific mystifications that have acquired a nearly religious allure.

The same can be said *a fortiori* about the concept of entropy, and what it may mean. John von Neumann put it best:

> "Whoever uses the term 'entropy' in a discussion always wins since no one knows what entropy really is" [4]

Little wonder that no one knows what entropy is, given that it appears no one knows what heat really is... Yet, heat engines have existed for hundreds of years. Still, the confusion between energy and entropy was intended by Rudolf Clausius himself, who coined the word entropy "from the Greek 'hê tropê', *transformation*", in which he replaced the feminine article "hê" with the prefix "en" to make the term "as similar as possible to the word *energy*" [5]. Yet, entropy is not energy - and heat, well, it is unclear, at best, just what kind of energy it is.

In the course of this work, we will repeatedly encounter these questions and the problems they raise. We may seek a priori definitions for the various notions involved - but, then, we will risk having to redefine them all over again once confronted with a systematic inconsistency. Or we may proceed heuristically, checking the validity of each proposed definition as it emerges from a process of articulation with experimental facts. For example, consider the statement: "temperature is a manifestation of the kinetic energy of motion of individual molecules of matter". We may accept that it is valid without assuming that it is the only such manifestation, or even a direct one. It could be that temperature is, instead, solely electromagnetic, a property of photons alone - and that it is these photons, their ratio and density of production at a certain energy level, which are a manifestation of the kinetic energy of molecules - an indicator of their average kinetic state in some volume of space. Or it could be that, while all nonionizing photons have a specific temperature, temperature in molar terms is the property of a dominant population of photons that are generated from the kinetic energy of free electrons - and thus, that any change in the latter, as measured by a change in temperature, forces a change, loss or gain be it, in the kinetic energy of the molecules of matter. As another example, we may consider the statement: "heat may be sensible or latent according to whether or not its energy content is expressed as a function of temperature". Again, it may be valid if considered phenomenologically: changes in sensible heat "content" are always accompanied by changes in temperature (though this is not necessarily the case when applied to sensible heat transfer), whereas the "content" of latent heat, e.g. of phase, may remain the same as temperature changes, or change at the same temperature. Yet, even if a molecular phase change results from absorption of sensible heat, the latent heat of phase, the so-called *enthalpy of state*, does not appear to consist of heat at all. And, just as we started out above, both realizations leave one wondering just what is sensible heat, if latent heat is no heat at all.

Cardwell's opening quote questions established thermodynamics - or the successive academic establishments of the same - as to whether they could have come this far, and still go further, without the contributions of outsiders ("amateurs or devotees"), without their full participation, without them having a voice, let alone a say on the matter. Yet and increasingly so over the past century, these outsiders have been effectively suppressed and their contributions discarded with no consideration, and often with much mockery and arrogance. It is all the more paradoxical, as the very emergence of thermodynamics witnesses to a nexus formed by the various contributions of independent lines of research carried on precisely by outsiders, on their own steam, so to speak - not just Carnot, Mayer and Joule, but Stirling, Clayperon, Ericsson, etc. Without them, the science of thermodynamics would not have seen the day. Just as - without contemporary independent contributions, the establishment of "modern science" and present-day thermodynamics is bound to become a barren pursuit mired in unending contradictions and confusions. However, Cardwell is still in error - as he treats science as a scene, the independent lines of research as opinions that require representation, the life of these amateurs as a tragedy, and the ultimate infertility of science - which we now see in all its glory in the pages of journals like *Nature* or *Science* - as the narrative of the greatest of tragedies. It is rather the greatest of stupidities - for the present-day establishment of science has come to the conclusions that nature is fuzzy and science just a narrative, and done so solely as a self-indulgent justification for its patent lack of consistency. It is closed not just to the opinions of outsiders that have valid contributions - it is *closed to facts*, whether unearthed analytically and experimentally by outsiders or by any insiders who, at some point, decide to publicly wash the dirt off the laundry. The advancement of science has been arrested by the congealment of a narrative in which science can never yield certainties. Just witness how molecular biology and biochemistry floundered in the *in silico* studies...Little wonder, then, no one can answer the question of what exactly heat is, even as we are told that the entire universe will eventually die from the entropy of its heat tending to a maximum...

1.2. Some guiding beacons of reference for what lies ahead: electromagnetic heat, thermokinetic heat, free electrons of state, modal and submodal photons, and massfree ambipolons

Amidst this fog of thermodynamics, it is virtually impossible to find a viable path that will extricate the understanding of heat energy from the present-day arbitrary closure of physical science in purely axiomatic considerations that make a point of ignoring what is not known or unknown, by a "make believe" in irrational abstrusities like those mentioned already. Ahead lies a long journey that only the patient minds will endure. Eventually, the path will become clear. For those who want to pursue it, we will now give a short "heads up" by providing some location beacons to illuminate the new path being charted in these monographs. The beacons are not axioms or apriori parameters, but working parameters of reference, markers of the undertaken trajectory whose location will become more definite as the contours of the chart will become more exact. These working parameters emerged on their own from the present investigation, but did so at the intersection with other findings from our published research in basic physics and chemistry. Without this background, most of the material will seem opaque to the reader.

Our first working parameter is that *sensible heat actually - that is, in the strictest sense - only exists in electromagnetic form.* We will prove the correctness of this statement over and over throughout the present book. We have previously shown evidence for our contention that all photons are massfree [6], and we will demonstrate that temperature is a direct index of the quantum energy of optothermal photons that modally predominate in a mole of substance. Though a radiative form of massfree energy, 'nonionizing' or optothermal photons do not travel far from their emitters [6], so that electromagnetic heat is only produced locally. Their constant modal production contributes to exert a primary (barometric) pressure that is internal to any volume of gas, just as it is internal to every physical system in every phase of matter - as long as the system is not engaged in fusion-driven nucleosynthesis, or in the exclusive production of "degenerate" "electron-pairs" and neutrons [7]. In effect, any physical system that has *a thermal aspect* presents an internal barometric pressure that constantly "seeks to match" the external barometric pressure. Thereby, the internal photons responsible for the temperature and the barometric pressure of any thermalized system are and must be constantly regenerated. As we shall amply see, the problem is a bit more complex than this. On one hand, all physical systems without exception are subject to internal and external electrodynamic pressures that are distinct from the corresponding barometric or electromagnetic pressures (including fugacity), and indirectly responsible for them. On the other hand, the effects of barometric pressure always depend on the distribution of *two* distinct molar classes of photons, modal *and submodal*. Furthermore, while molar temperature depends solely on the modal class, the heat capacity of a given phase of a substance or system turns out to also depend on a function that invokes both classes. The thermodynamic consequences of taking at last into account these fundamental features of the electromagnetic field(s) of sensible heat are bound to astonish the attentive reader, just as they astonished us when we uncovered them.

Nevertheless, one may *operationally* state that sensible heat also includes the thermokinetic energy of the molecules of a substance, since the inelastic collisional effects this energy causes are felt ("sensed") biologically as heat, and physically manifest themselves by the production of rather low-frequency optothermal photons (LFOTs). Of course, the general concept of sensible heat has always been thought - in the history of thermodynamics - to encompass the thermokinetic energy of molecules. In effect, the dominance of statistical mechanics in thermodynamics is directly attributable to a physical treatment of heat that only and exclusively considers the kinetic energy of molecules with the various stochastic schemes to determine their velocity distribution. Most of the flaws of thermodynamics arise from the inability to consider what is the electromagnetic heat of state, and to separate it from what is the thermokinetic molecular heat of state. We will systematically advance the notion that the latter is defined by the *isochoric heat content* of a substance or system - and we may call this our second working parameter.

But, then again, molecular thermokinetic energy does not actually seem to consist of heat per se, and the heat it locally causes is likely just the heat of the photons released from that thermokinetic energy when molecules undergo inelastic collisions. Moreover, we will find that for every molecular substance in any of the different phases of matter, the photon content at any one time is in a direct and variable relation to the *modal thermokinetic energy* of the substance's individual molecules. Sensible heat, then, in its strictest physical sense, is just a direct manifestation of optothermal photon production. Yet, operationally and in a wider sense, it even includes the thermokinetic energy of a substance's molecules. In due course, we will unravel exactly what such duality of sensible heat physically means and entails. It will have tremendous consequences - unsurmised up until now - for one's understanding of heat engines.

If the kinetic energy of molecules originates optothermal photons through collisional dynamics, including viscous shearing (so-called friction) and (electric) "field decceleration", and this is why and how molecular kinetics generates sensible heat, then what applies to molecules applies *a fortiori* to electrons. Furthernore, collisions of free electrons with molecules produce nonionizing photons with much greater energies than are produced by inter-molecular collisions ("at the end of the day" inter-molecular collisions largely reduce to collisions which involve electrons that are covalently bound to molecules).

Thus, the third major working parameter - that all kinetic energy is electric, whether overtly or covertly so. Cosmologically, we have demonstrated how gravitational interactions follow from hidden electric processes [8-9], and how the mass-energy of every particle of matter is electrically ordered [8, 10]. It may well be that thermokinetic energy is just a subspecies of the electrokinetic energy of molecules. It may actually designate solely the energy associated with a particular type of motion affected to "electrically-neutral" molecules. Looking ahead, we will propose that its exclusive reference is "molecular free rotation", and that its deployment ultimately abides by the "electric field" of a molecule, such that domains of diamagnetic and paramagnetic ordering of the directions of molecular rotation are possible. Amongst other consequences, we will critically question whether the heat capacity extrapolations to zero Kelvin made from ultra-cryogenic temperatures and based on Debye's theory, are valid at all.

In most substances, kinetic energy is recognized as overtly electric when it is the energy of free ions or massbound charges. When ions are bound by salt linkages or covalently combined into neutral molecules or even free radicals, their kinetic energy is no longer recognized as being electric, but as being thermal (or chemical). The dominant presence of neutral molecules in a substance is itself the result of hidden electric interactions. In liquid and semi-solid phases, the acid-base equilibrium keeps positive ions in check by a balance that is not just performed by bases (negative ions in the wide sense), but also by *chemically-active free electrons* (negatrons) that deploy a "redox" potential. These free electrons are already accounted for in the ionic and redox balances of a solution or gel. However, as we shall come to realize, there is an even larger class of free electrons (modal and submodal) in every phase of a substance, which respond to the electrodynamic pressure of standing electric waves in every medium, whether these are constant or changing. These free electrons *of state* constantly absorb the underlying energy of the standing electric field, and constantly discharge their electrokinetic energy to generate the modal and submodal electromagnetic "heats" of state that are responsible for the molar effects of temperature and the internal pressure of a system.

A neutral molecule essentially comprises opposing electric charges - nuclear and covalent - that cancel one another, or are electrically matched. In the atomic Table of Elements, only the noble gases are electrically equilibrated or satisfied. In other words, the sum of their total covalent bond momenta is zero. Yet, this does not mean that they cannot be polarized electrically, or that their free revolution is not oriented along preferred electric axes. All other atoms or molecules present what is called net dipole-moments because their bond momenta sums are non-zero. In other words, most neutral molecules are discretely electrically polarized. Particularly in liquid phases, neutral molecules present complex chemical equilibria between a neutral (or recombined) state and a state of covalent bond dissociation into ions or free radicals. The most poignant example is offered by liquid water - a neutral molecule with a net dipole moment that is balanced against the molecule's ionic products (heterolysis) as a function of pH, but also balanced against its homolytic dissociation into free radicals as a function of redox potentials. The pH parameter only measures the heterolytic dissociation of water or an aqueous solution as a function of volumetric concentration and the acid activity of positively charged protons (their electrokinetic activity), against the neutral background of water molecules (against their thermokinetic activity as reference state). However, when considering the intermingling of heterolysis and homolysis pathways for the dissociation of water, only the aetherometric measurement of the log of electron concentration [11] can yield the total equilibrium between water and the products of the two dissociation and re-association pathways:

$$p[e^-] = -\log\{\{[H^+][O][e^-]\}/[H_2O]\}+\log\{\{[H^+][O]\}/[H_2O]\}$$

Here, the electrokinetic energy densities of both protons and electrons are taken together against the neutral background of water molecules, and so is the concentration of neutral monoatomic oxygen atoms (free radicals). The latter, together with the water molecules, are also kineticized - also in motion - but the electric nature of their motion is covert: it appears as "thermokinetic energy" and is considered to be randomistic. Yet the rotary motion of such molecules depends, at all times, on the preferred orientations of their net internal dipole moments - effectively, upon their net electric angular momenta - that are adopted in response to the motions of surrounding free protons and free electrons. And as with all free electrons, the neutral molecules sustain their rotation by absorbing energy from any standing electric waves and any photons they may intercept.

Even when molecules are said to have no net dipole moment - H_2 is often cited here as example - their states of motion (including translatory motion) distort them so that transient dipole moments constantly exist: for example, between H^+ and H^- in H_2. Most importantly - and as is well known in physical chemistry - dipole moments induce the conversion of the translational energy of molecules into *tumbling motions* - what chemists confusedly call *rotation* [12] - as either pole of the molecule seeks opposing vectors of translational motion in an electric field (note that more than one dipole moment can exist in the same molecule, and that a field may be complex and have superimposed gradients with distinct axial polarizations). We shall see how rotary-tumbling motion acquires particular importance in liquid phases.

So, we must keep in mind that the log of electron concentration [11] measures the total equilibrium between water and its products, as well as the total concentration of only a certain number or class of free electrons in water: those that are chemically active - that is, it *only measures the total concentration of those free electrons which potentially enter into the composition of water and its homolytic and heterolytic stages (ions and free radicals) of dissociation or association*. It does *not* take into account the number of free electrons that at any one time in every substance (e.g. in liquid water, as well as in gases and solids, including ice) spend their kinetic energy in the continual production of modal and submodal photons responsible for the temperature and barometric pressure effects. These modal and submodal electrons are what we came to designate as "free electrons of state". They exist at substantially greater concentrations than the free electrons involved in the chemical cycles of the composition and dissociation of water. The modal or primary class is directly responsible for the molal electromagnetic heat of every substance in any phase, and the two classes together generate the modal and submodal photons responsible for the internal barometric pressure of a substance, system or milieu.

Our disquisition, then, will be able to do something that thermodynamics today cannot even dream of: to demonstrate that thermokinetic and electromagnetic "heats" - and all of their parameters of pressure, volume and temperature - are electrodynamic productions where "free electrons of state" play the dominant role among positive ions and neutral molecules. This stands in distinction from the chemical activity of acid-base reactions, where two main types of free massbound charges - protons and electrons - play the critical role; and equally in distinction from the chemical activity of free-radical reactions that are driven by electrically neutral molecules that present one or more unpaired covalent electrons (e.g. molecular oxygen, which is a stable diradical). Note that a simpler definition of an atomic free radical presents it as a neutral molecule whose covalency charge (electronic) matches the nuclear (protonic) charge.

We will go further, much further - as we shall demonstrate that the electrodynamic interactions which dominate all others, even those which involve the "free electrons of state", are massfree in nature. More specifically, we will show that the ultimate electrodynamic interactions that underpin the entire physics of heat and sound involve massfree electric charges - which we have termed ambipolons [14-17] - that cannot be subsumed under the rubrics of electrokinetics, thermokinetics or electromagnetism. When we speak of electrodynamic pressure exerted by standing electric waves, we are referring to fluxes of massfree ambipolons. These can be trapped in cavities whose boundaries can reflect them, and are emitted from the electrokinetic energy of free electrons during the coordinated magnetic tumbling of an electron cluster [13], or from parallel processes that coordinate the magnetic tumbling of other massbound charges, such as they apply to free plasmas and specific nuclear fusion reactions. The very terrestrial atmosphere is the joint product of solar and terrestrial ambipolons that ultimately source both the electrokinetic energy of its free electrons of state and the thermokinetic energy of its molecules.

Thus, a profound unity of physics will emerge from our totally novel approach to the science of heat - one that explains how thermokinetic and electromagnetic heats are electrodynamically generated, and constantly regenerated, by ordered massfree and massbound electric interactions. The stability of these interactions determines the complex equilibria between the thermokinetic dynamics of "electrically-neutral" molecules and the average photon-energy field that is constantly being produced, absorbed and re-emitted as the *real* sensible heat content of a molecular substance.

The three working parameters also subtend an important notion, which appears, at first, difficult to grasp: that, whether we say thermokinetic, electrokinetic or electromagnetic, we are still and solely referring to massfree energy, but one that is transiently bound to molecules and ions (including free electrons), or discharged in the form of massless photons or, still, massfree ambipolons. To fully understand this, let us recap the foundations of Aetherometry, an endeavour that we began back in 1995. Massfree energy exists in two distinct forms: one, fundamental and electric, which we have termed ambipolar, and the other, transient and electromagnetic - the quantum photon energy. Both forms of massless energy are radiative, and may therefore be absorbed by massbound particles, including monopolar charges. Whereas *nonionizing* optothermal photons are always absorbed proximally, ambipolar energy may be absorbed distally from the source. It that way, it forms travelling waves, just as *ionizing* photons do, even if the wave structure of ambipolons is rather distinct from that of any photons. Once absorbed, massfree electric energy becomes kinetic energy - the thermokinetic energy of molecules, or the electrokinetic energy of ions - thereby temporarily becoming massbound energy, that is, bound to mass-carrying particles of matter (what aetherometrically we term mass-energy particles, e.g. an electron, a proton, a neutron, a molecule, etc). But kinetic energy itself (the kineton) remains massless. It is only transitorily associated with mass-energy, and remains distinct from the latter. Thus, it may be released from the mass-carrying particles in either electromagnetic or ambipolar form (the latter with the caveat that it is always a joint or cooperative production by a set of monopolar charges [13]). It follows that when one says that a system is isolated, that it has no incoming or outgoing fluxes of either energy or matter, one is talking about a fiction. At best one may describe a system that is closed to molecular flows of matter. But any such a system, as we shall see, will necessarily receive and emit massfree energy, be it electric (ambipolons) or electromagnetic (photons). Further, emission of radiant energy from such a closed system is always the result of the loss of some form of kinetic energy from the molecules and free electrons composing the system.

Knowledge of these working parameters or guiding beacons is not necessary prior to reading our disquisition. They will emerge during its course at the appropriate moment, on their own. In effect, we will begin our investigation - as well as every chapter - by expounding first what is the accepted thermodynamic science on the relevant subjects. This will circumscribe the boundaries of thermodynamics and physical chemistry, and permit us at last to think beyond them. That is where these beacons will be of use.

1.3. A new methodological approach to the science of thermodynamics

Newton's Differential Calculus reached its scientific apogee by application to the description of the motion of solid bodies and the enunciation of a general, mechanical theory of gravitation, even as it appropriated and displaced Kepler's harmonic geometrism. But the calculus of derivatives would, a century later, reach another apex, when it axiomatized classical thermodynamics by culminating in the work of Clausius that introduced the entropy function to restate the Second Law. Differential calculus provided a physico-mathematical framework that at last presented a mechanical understanding of how heat flows "reversibly and irreversibly", even if this came at the cost of modelling physical substances as collections of dimensionless points endowed with abstract motions, and the physical nature of heat qua energy remained rather opaque. It also made possible the subsequent development of stochastic thermodynamics out of the failures of the old kinetic theory (inability to produce a universal temperature scale; inability to accurately predict the molecular velocities of polyatomic gases; etc). Long before elaborations of quantum-mechanics further modified the stochastic approach, thermodynamics had become a science of large numbers (a mass-statistical theory) ruled by randomizing processes, since heat ultimately tended towards dissipation - toward "a macroscopic state of disorder and a maximum of symmetry" [18]. Thus, Boltzmann sought to apply combinatorial analysis to ascertain the number of probability distributions of "molecular trajectories" or velocities in distinct compartments or molecular states. Disorder arose from the wide dispersion of molecular velocities, whereas coherent motion corresponded to such a low number of probabilities (or rather, "complexions") that it virtually rendered dissymetry or "spontaneous order" as "the most improbable". Boltzmann's approach would lay the foundation to the notion that there is a dynamic competition between entropy and free energy. This redefined the notion of equilibrium as an attractor that, while it favoured entropy-driven molecular disorder and heat dissipation at high temperatures, favoured, instead, free-energy-driven formation of ordered structures at low temperatures (the concept of structure as congealment).

But the hypothesis of assigning an equal probability to each molecular state in any given population came under scrutiny a century later, when molecular structure was observed to arise at high temperatures. Prigogine and Stengers pointed out that:

> "In the case of the Bénard instability it is a fluctuation, a microscopic convection current, which would have been doomed to regression by the application of Boltzmann's order principle, but which on the contrary is amplified until it invades the whole system." [19]

The fluctuation itself becomes stabilized and generates "a new molecular order". This thought sourced Prigogine's now famous paradoxical concept of "dissipative structures" which operate in far-from-equilibrium conditions and obtain ("supramolecular") structure and order out of thermal dissipation or energy waste. A new science of thermodynamics then appeared to emerge, one that better qualified as thermal energetics: how energy instabilities can be scoped into forming stable systems that do not obey classical stochastic theory:

> "In far-from-equilibrium conditions, the concept of probability that underlies Boltzmann's order principle is no longer valid in that the structures we observe do not correspond to a maximum of complexions. Neither can they be related to a minimum of free energy $F = E - TS$. The tendency toward levelling out and forgetting initial conditions is no longer a general property." [19]

Yet, the concrete analysis of the dynamics of heat remained mechanistic. As had happened with Newton's general theory of gravitation, there was still no perceived need to base the theory of the dynamics of heat on more fundamental energy functions. Heat remained treated simply as an expression of the kinetic energy of molecules (convection currents, molecular diffusion, energy dissipation, etc). As we will show later in some detail, it even continued to remain unclear whether it was the product of entropy and temperature that constituted energy, or entropy itself that did so. Physically-seated functions (such as heat content) became, at best, mere mathematical abstractions to which values of potential were attributable.

Similar abstrusities had once been introduced into electrodynamics by Maxwell and Lorenz. Yet, the algebraic treatment of electricity (Ohm's Law, Kirchoff's Laws) remained solid - even if the variety of magnetization states remained prisoner of the calculus of probabilities, and the Law of Electrodynamics in nearly all variants has been revealed to be in many an error. Our own work in this vast field has shown proof that electric and magnetic properties and interactions, including the structure of mass-energy, can be treated more exactly by a novel functionalist algebra. The conclusion is that not all electric and magnetic processes are quantum-mechanical, and that wave-mechanics has failed both by its fundamental inability to take into account massfree electric interactions, and by its twisted account of the roles of electromagnetic fields in practically all relevant physical processes and productions (from the photoelectric effect to the temperature or pressure of a system, to pair creation/destruction, generation of nuclear gluons, etc). Moreover, we have provided an extensive demonstration [20] of how the luminal acceleration of particles abides not by formal relativistic constraints, but by an algebra of finite energy quantities that invoke the universal quantum of charge and the conservation of mass-energy.

If there were a comparable universal quantum of heat, our argument would have been made for us. But even if this is not the case, it is most unlikely that if a functionalist algebraic theory of electrodynamics can be, and was, enunciated, a comparable theory of thermodynamics would not and could not. If energy abides by universal laws, the algebraic analysis of thermal energy cannot be any different in fundamental functions from the algebraic analysis of electric energy. It is not tenable that energy would behave one way if it is thermal, and in a different way if it is electric. It is not even tenable that the physical functions of electric energy would not be mirrored in the physical functions of heat. As we will show, indeed they are mirrored, even if no universal quantum of heat - no universal linear momentum or angular momentum of heat - exists. The pages that follow are dedicated to slowly teasing out the new mathematical theory of heat, one that elucidates most of the shortcomings of the established science of thermodynamics, and brings to the surface the electrodynamic processes that generate the phenomena (plural) one calls 'heat'.

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