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Article

On the Differences Between a Person and a Particle

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Abstract

A digression or dialectic on seemingly innocuous question is 'what is the difference between a person and a particle?' is pursued. Although the variety of physical properties and behaviors of these two obviously differentiated systems may at first render the consideration of the question trivial, there do remain some issues of practical interest. The purpose of this paper is to investigate and elucidate a few of the differences between systems containing people and those consisting of particles in order to increase the efficacy of thermodynamics as applied to ecosystems.

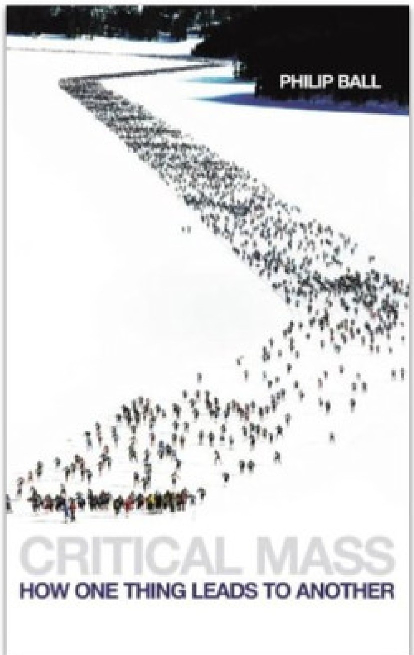
Introduction

In 1842, French philosopher Auguste Comte, in his *Discourse on Positive Philosophy*, strived to bring the work of previous scientists full-circle in developing a physics of human society:[1]

> "Now that the human mind has grasped the celestial and terrestrial physics, mechanical and chemical, organic physics, both vegetable and animal, there remains one science, to fill up the series of sciences of observation - social physics. This is what men have now most need of; and this it is the principle aim of the present work to establish."

In this paper, the goal is much more humble. Here the comparison between ecosystems containing large numbers of people and particles will be further elucidated. The purpose of this work is to query some of the fundamentals developed in the thermodynamic theory of ecosystems, in which the interacting entities of interest are no longer molecules and heterogeneous mixtures, but people and ecosystems.

Discussions on the nature of a 'social physics' are not new. Greek philosopher Lucretius, in his 55 BC *On the Nature of Things* describes all aspects of the fickle-fated human condition as fundamentally being subject to nature's laws. German polyintellect Johann Goethe's self-described 'best book' was *Elective Affinities*, a powerful demonstration of affinity chemistry to human relationships. Contemporary examples of social physics, developed under the auspices of modern physics, can be found in German solid state physicist Jurgen Mimke's 2000 article 'Society as a Many-Particle System' and more recently in English chemical physicist Philip Ball's 2004 *Critical Mass*, on the cover of which one can discern the outline of a particle or flow of particles view of humans:[2]



"Out of [statistical physics] [a] new social physics has emerged. Things have come full circle, as physicists have asked 'might we see in society some of the same phenomena that we find in collections of interacting **particles**?' If we substitute atoms and molecules by people, or cars, or market traders, or businesses, can we use statistical physics to understand some of the phenomena that arise in the real world?"
— Philip Ball (2003), "The Physics of Society"[3]

Thus physics, albeit slowly, is finding its place in the science of society. In this direction, herein we will apply this emerging framework to ecosystems and society via thermodynamics.

Thermodynamics as the science of ecosystems and society

Thermodynamics, as the science of energy puts few requirements on the physical characteristics of the systems under inquiry. Rather, it focuses on the application of its two major laws: The first law of thermodynamics is the statement of conservation of energy. The second law dictates that the entropy of an ideal isolated universe must increase. Simply put, thermodynamic systems must remain lawful. However, the practical application of the first and second laws of thermodynamics to large macroscopic systems, e.g. ecosystems such as human societies remains largely illusive. Despite the monumental advances made in both theory and measurement, this does not change the cardinal truth recognized by Helmholtz that:[4]

"All laws must ultimately be merged into laws of motion."

Fundamentally, microscopic configuration leads to the formation of macroscopic structure, but the treatment of large macroscopic systems with increasing physical scale using classical thermodynamics alone requires attentive deliberation, as the time evolution of many macroscopic systems also impose change from the larger scales downward. An example relevant to human evolution is the case of gene expression, which can be seen as a series of chemical changes in informed autocatalytic processes.[5] Such changes cannot easily be subsumed into the derivations of classical mechanics, electromagnetism, and thermodynamics because the laws of motion derived from the classical approaches lack the interlinking hierarchical physical control mechanisms separating the quantum world from that of Manhattan at mid-day.

There can be little doubt that formally, ecosystems can be described using the laws of thermodynamics, many of which can feasibly be derived to include terms describing the change in a system's energy, for a given configuration, in terms of the work performed and heat exchanged. The difficulty lies in making *physical sense* of a particular formulation's individual terms, and it is indeed this that poses the major challenge to the practical application of an ecological thermodynamics to human society. We can however, begin to investigate the dynamics and development of societies with the well-worn formulations of classical thermodynamics and statistical mechanics.

In describing the spatial and temporal patterns formed by the development of animate systems, English-born Canadian physical chemist Lionel Harrison's 1993 tripartite division of physical chemistry, the study of matter-energy interactions at the atomic scale, into equilibrium, kinetics, and structure can to some extent be elucidated via statistical thermodynamics, but as recognized by American engineer Willard Gibbs himself, there arise considerable difficulties in obtaining the requisite simultaneous view of all three.[6] Nonetheless, we will endeavor to discuss the differences between a person and a particle, chiefly from the point of view of statistical mechanics as it deals with predictions of systems composed of large number counts of entities interacting in a non-correlated but lawful manner.

Person and particle systems as an N-body problem

The notion of a particle in this paper applies to a macroscopic, idealized, spherical entity. The size of the particle is assumed to be on the same scale as that of an adult human; here we may take a radius of 1 m as a simple reference. The concept of a thermodynamic state is given simply as the ensemble of its physical quantities (temperature, pressure, etc.) which characterize the system, irrespective of its surroundings and its history.[7] This lack of a historical precedent in the depiction of the state of a society may indeed be one of the largest conceptual difficulties faced when investigating ecosystems from a purely thermodynamic perspective. Due to the enormous number of interactions between the entities in our system, such as the crowd depicted below left, we can apply the law of large numbers in order to find deterministic relations between system variables such as pressure and temperature, even if the inherent motion of the individual entities themselves is random.

This upscaling of decoherent, chaotic motion at the microscale into predictable macroscopic system behavior is one of the main benefits of the statistical mechanics approach, and aids in defining the notion of the thermodynamic limit, the scale at which explicit knowledge of the individual particle's behavior becomes necessary. It is also worth noting herein that the particle of interest is a classical particle in the sense that due to its physical size, quantum effects can be ignored, wherein we assume that the classical approximation holds regardless of its trajectory, on the logic that the particle's classical action is large in comparison to Planck's quantum of action, and any small deviation of the particle's path on the classical scale will not appreciably change the relation.[8]

People **Particles**

Can we abstract the dynamics of a joyful crowd to a system of heterogeneous, interacting particles?

The study of novel systems consisting of human-sized particles thus returns us to the study of the N-body problem. In this work, a mechanical philosophy of matter is adopted where ecosystems and societies can be fundamentally seen as many body, statistical systems. Using statistical mechanics, the behavior of a many body system is *not* considered from the point of view of the individual, but rather is seen as the *culmination* of inevitable effects in collective action.[1] The crux of this problem, from the statistical mechanics point of view, has already been well-defined by Austrian physicist Erwin Schrodinger:[9]

> "There is, essentially, only one problem in statistical thermodynamics: the distribution of a given amount of energy E over N identical systems."

Thus in order to study this problem in detail, it is necessary to apply the techniques of statistical mechanics. At the onset, we do not care much whether our system consists of people or particles.

A statistical mechanics approach

The study of our ecosystem, whether its inhabitants are considered explicitly as people, or simplified to particle form, is in essence the study of the distribution of the system's energy. In treating this problem, there have been traditionally two ways of viewing the partitioning of system energy in consideration of its constituents and particular configuration.

The first is the kinetic approach taken by physicists Scott James Maxwell and Austrian Ludwig Boltzmann, and is applicable to systems consisting of a large number of *identical* particles and leads to estimates of the 'private' energies of each particle, ultimately determining distributions for each of the possible configurations. This approach provided the first insights into the behavior of ideal gases and helped forward the atomic hypothesis, but is too restrictive to our case, where each individual particle can be considered unique, leading to the description of such systems as an infinite number of interacting oscillators in an infinite number of configurations.

The second approach is that taken by Gibbs, and has in its ingenious formulation the inherent quality of general applicability to any and every physical system. In this case, we isolate the system and at the same time make N identical copies. Allowing for a weak interaction between copies, we find that the system under observation is in a heat bath with the N-1 others. The interesting result of this formulation allows us to do away with the assumption of identical particles (as differences can be identified as one of the N system variants), and concomitantly removes the notion of any single system ever having a 'pure state' at all.[9]

The statistical mechanics approach of the person or particle system stems from the recognition that the basis of equivalence of heat and work can be partially elucidated via the kinetic theory of gases, a mechanistic formulation of a many body system following classical mechanics, which allows us to *approximate* thermal phenomena as the disordered motions and interactions of its constituents. From this perspective, a huge gain is already made in that we have found a way to simplify the $6N$ variables (positions and momenta) required to explicitly define the particle system.[10] The great power of thermodynamics thus lies in its ability to correctly deduce the behavior of macroscopic systems with little or no inherent knowledge of the microscopic nature of the system itself.[11] Systems containing large number counts of human individuals, however, can obviously be differentiated from those of macroscopic particles. The interest here now lies in investigating a few specific considerations that may provide slightly more information than the classic statistical mechanics approach alone.

Key considerations

Recognizing that the utility of the statistical mechanics approach is tempered with a loss of microscale fidelity does not mean that we must cast away all hope of gaining a fine-grained perspective. Instead, we may take a closer look at a few of the required assumptions behind the approach in order to gain insight as to how individual particles or people may behave within the larger context of the observed ecosystem. In going about this, we must recognize that our ecosystem is composed of elementary units such as particles, and that the large number of these point elements can be subsumed into groups of elements. Furthermore, we can safely assume that the distances between groups are always much larger than the distances between particles within a group. This is analogous to the assumption that the intra-group forces are much larger than the inter-group forces.[12] Thus even when taking the statistical mechanics approach, we can still allow for simplified kinetic expressions differentiating between the interactions within, and between the groups of individuals we may wish to study.

Following the first law of thermodynamics, we must apply the principle of conservation of energy to our system. The simplest way to do so is to divide up the total system energy into the aforementioned private energies of first the groups of particles, and then allocate the energy of each individual as a fractional portion of each group. We can further differentiate between the kinetic and potential energies, assuming that the particles interact with forces which are derived from the potential energies.[12] The configuration of the system itself begins to play an important role because the distribution of potential energies are themselves primarily functions of the distances between groups and between the individual elements. As previously mentioned, our systems are continuously driven by forces, and these driving forces are derivable from their potentials. Thus in most cases, the inter-group potential is smaller than that of the intra-group potential, commensurate with the strength of the forces acting on, and within groups as well. This formulation results in a total potential energy with group, individual, and coupling contributions.

In addition to recognizing that for simple systems such as mixtures of ideal gases we can accurately predict thermodynamic variables such as temperature and pressure, we would like to apply this approach to more sophisticated systems consisting of people, and people abstracted into particle form. Following Chinese applied mathematicians Hao Ge and Chinese-born American applied mathematician Hong Qian, we can describe our individuated particle system in terms of a Markov model, where all possible future states depend only on the current state, and not on the entire history of previous events.[13] The Markov model approach is thus somewhat affiliated with the framework of classical thermodynamics, where path-independent cyclical processes play a major role.[Q3] Additionally, this formulation has the benefit of keeping the possibility of unique entities, in case we wish to suddenly switch back to the person-based formulation, since the transition probabilities used to describe the individual system processes do not explicitly require the assumption of uniqueness.

Furthermore, we could view our particle system at a rate in which the processes can be assumed to be very close to isothermal and isobaric. In such a case, we see that the total energy of our system changes primarily as the interplay between the internal energy and work exchanged between the society and its surroundings, i.e. the 'societal enthalpy', and the energy dissipation due to lost work, chemical reactions, mass exchange, friction, and heat transfer, i.e. the entropic contribution. This juxtaposition of available energy and uncompensated heat is the Gibbs 'free energy of a society', wherein here a society is a heterogeneous mixture. It is this energy which following the Lewis inequality, spontaneously decreases when forming new configurations. Considerable work has been done by Russian physical chemist Georgi Gladyshev in developing a general theory of hierarchical system evolution based on the Gibbs free energy.[14] Here it is interesting to note that a 'social system' can best be seen as relaxing *towards* equilibrium, but never actually achieves it.[Q1] Society and ecosystems are fundamentally nonequilibrium systems.[Q2] Taking a vantage point where the changes in pressure and temperature are small allows for a more simplified, classical view of the development of the system of interest. What this means for both our particle and person systems is that they cannot be further abstracted to a state of rest. Our system is continuously *driven*.

In the previous discussion, we have seen how the person or particle systems can both be viewed as a many-body problem. Following Schrodinger, it was shown that the fundamental question in such problems revolves around the allocation of the system's total energy amongst the individual system entities. In investigating this further, some basic concepts taken from statistical mechanics, an offshoot of classical thermodynamics, were introduced. A few key considerations have been discussed as to how we can study group behavior within the ensemble of particles using a primitive kinetic approach, so as retain some valuable information regarding the behavior of the individual. It was suggested that the result of individual behavior can be expressed in the form of a Markov model, and that the use of transition probabilities may allow for the study of unique entities. Finally, a brief discussion of the system in terms of classical thermodynamics was presented, where the use of the Gibbs free energy function was pointed out as the guiding indicator of ecosystem (or societal) change. However, unlike the ideal systems dealt with in classical thermodynamics, our systems are fundamentally irreversible and never reach equilibrium.[Q4] This leads to the realization that our system and its development in time and space must be considered as being continuously driven. How then does this driven system now appear differently if seen as consisting of persons or as particles?

Differences between a person and a particle

The first difficulty we face in applying the statistical mechanics approach to the human population is the issue of finding a proper classification. From the particle perspective, this is straightforward in that we can use only the radius to classify the geometry of each individual. Every particle need not have the same radius, or temperature, or even mass density, but the *geometry* of the individual entities can be simply and rigorously described with the use of a single parameter. Thus, the division of a system's energy over the particles, considering their substance and configuration can be related to a single, well-defined geometric property of the individuals themselves. In the case of a person, it is not possible to formulate an expression for a person's geometry. Thus, the development of the shape of a person alone, and the problem posed by its mathematical characterization creates difficulty in the direct application and transference of statistical mechanics principles to the study of human populations and ecosystems.

The second and more substantial challenge in abstracting people as particles when considering ecosystems from the statistical mechanics perspective is that of interaction. Any system containing moving parts is usually treated as though the parts are moving so slow relative to the particle motions as to be negligible. In macroscopic person systems, this is clearly not the case. The time evolution of macroscopic systems is governed by the lawful tinkering of nature, and it is the result of the multitude of interactions to which we ascribe a system's developing configuration.[15] How can we consider the system's design leading to a plane take-off in terms of the energies of interaction, or the change in internal energy of a bus full of human particles as it is suddenly taken hostage? The forces governing human interactions are more likely to be electromagnetic due to the brain's electrochemical nature, where environmental pressure and temperature are expected to play lesser roles.[16] Furthermore, the primitive kinetics of the particle simplification of human systems, at least those proposed here, are simply too severe to allow adequate treatment using statistical mechanics because it lacks the specification necessary to deliver meaningful results.

Finally, we come to the most pressing issue separating a person from a particle; it is fundamentally one of control. The dynamics of our ideal particle system follow the laws of motion just as that of any human system, so if the physical laws are the same, then what is the source of any discrepancy in our abstraction of the human system into a particle one? Our problem comes from the constraint or regulation of the system, its *principle control*. For any physical system, the principle control is a *set* of constraints which holds between certain degrees of freedom, but does not lead to completely rigid configuration.[17] Thus without going into a great level of detail, it can be seen that the major challenge in representing a system of people as a system of particles is determining the proper set of constraints which can be used to most accurately map the behavior of the more complex (person) system onto a simpler system (particle). These relations have not yet been found.

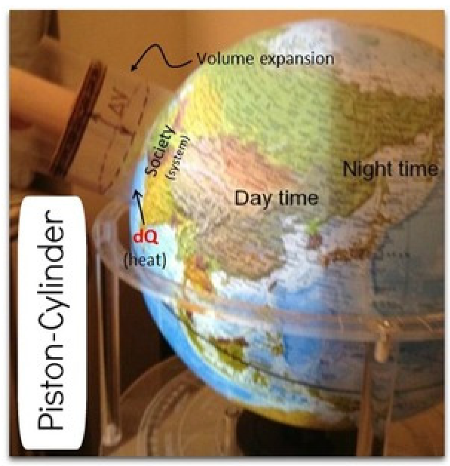
Objections

Not all scientists, to note, are amenable to the use of particle models for humans, for reasons which are difficult to pin down. French sociophysicist Serge Galam in 2004 commented the following:[18]

> "To suggest that humans could behave like atoms was looked upon as a blasphemy to both hard science and human complexity, a total nonsense, something to be condemned. And it has been indeed condemned during the last fifteen years."

Likewise, during the 2009 debated between Irish physicist Philip Moriarty and American electrochemical engineer Libb Thims, on the question of whether or not various arrangements of students in a field have quantifiable measures of entropy, a debate involving a number of noted thermodynamicists, such as French physicist Pierre Perrot, author of the 1998 *An A to Z Dictionary of Thermodynamics*, German physicist Ingo Muller, author of the 2007 *A History of Thermodynamics*, German physicist Wolfgang Muschik, senior editor of the *Journal of Non-Equilibrium Thermodynamics*, among others, the following theoretical point of view expressed by Thims:[19]

> "Every single one day of rotation of the earth constitutes one Carnot cycle. Expansion stroke: Heat is added (daytime) to the system (surface of the earth), the **particles** (human molecules) become active and expand outward, doing work in the process (occupation); contraction stroke: heat is removed (nighttime) from the system (surface of the earth), the particles (human molecules) begin to deactivate expanding inward (towards their bed), doing a reverse work in the process. This is all basic thermodynamics."



was, according to Moriarty, a former professor of thermal physics, to quote, but the 'product of a deranged imagination.'[20] Hence, in sum, the 'particle' model of humans is not at all an agreed upon method of investigation.

Overview

Systems in which a person is abstracted to a macroscopic particle can only be partially considered from the statistical mechanics point of view, largely due to the requirement that the entities are simplified into energetic classes. However, it is also possible to examine large macroscopic systems via the Gibbs free energy relation. From this vantage point, the disparities between a person and a particle become less differentiated as higher level interactions can be accounted for in terms of enthalpy and entropy.

Difficulties may arise in the simplification of the individual's interactions with their surroundings. Although it is mathematically possible to describe some the kinetics of human societies in terms of inter- and intra-group interactions, the inclusion of technological objects and co-development with inanimate systems makes a clear separation of society and surroundings a daunting task.

The largest difference between the person or particle approach however, lies in the descriptions of the hierarchical control mechanisms governing the system dynamics, which for particles are very different than for those of people. Here the author predicts that the use of concepts borrowed from classical thermodynamics, electromagnetism, and mechanics as applied to ecosystems such as human societies will remain severely limited until the details of principle control can be explicitly included in formulations developed to accurately predict their evolution.

Conclusions

In closing, it is the author's sincere hope that those who consider theories where the actions and interactions between human individuals are treated as equivalent particles should address the considerations expressed in this paper. It has been shown that there exist fundamental physical differences in considering systems containing people or particles which extend beyond the trivial.

It may also be noted that Gibbs himself can perhaps provide us with insight into the novel question posed in this work: 'what is the difference between a person and a particle', as follows:[6]

> "...it should be distinctly stated, that if the results obtained when the numbers of degrees of freedom are enormous coincide sensibly with the general laws of thermodynamics, however interesting and significant this coincidence may be, we are still far from having explained the phenomena of nature with respect to these laws. For, as compared with the case of nature, the systems which we have considered are of an ideal simplicity."

We must therefore be wary of vanguard attempts which in their lucrative offer of *ideal simplicity* serve only to rob us of a deeper, more meaningful awareness of nature's wild convolutions. The difference between a person and a particle is fundamentally one of perspective. Ideally there is no difference, but in reality there is.

> "In relation to society: *we are the* **particles** ... our glance must be directed towards the systems which surround the particles in order to better understand their interactive and evolutionary dynamics."
>
> — Joel de Rosnay (1975), *The Macroscope: a New Scientific System*

Variables table

The following—on the protocol of American economist Irving Fisher's 1892 mechanics-to-economics variables table, wherein he states explicitly 'a particle (in mechanics) corresponds to an individual (in economics)' —is the author's thermodynamics-to-ecosystems variables table:

Thermodynamics	**Ecosystems**
Particle / Ideal sphere (1-m in diameter)	Person
Societal enthalpy	Thermodynamic enthalpy
Free energy of a society	Thermodynamic free energy
Entropic contribution	Thermodynamic entropy
Boundary	Ecosystem boundary

Editorial questions

Q1. Re: 'a 'social system' can best be seen as relaxing *towards* equilibrium, but never actually achieves it', what is this supposed to mean?

Q2. (a) Re: 'Society and ecosystems are fundamentally nonequilibrium systems', what does this mean? Can you graphically, e.g. potential vs. extent graph (ref b), explain what you envision here?

(b) eoht.info/page/HCT+|+Fitness+landscapes

Q3. Explain Markov model in more detail, for readers not familiar with this, and in particular how you envisage this model applying to social/ecosystems.

Q4. (a) Re: 'our systems are fundamentally irreversible and never reach equilibrium', what exactly do you mean by this statement? What variables, differentiation conditions, or description do you use to justify this point of view?

(b) Historical excursions down this line of reasoning often tend to yield absurd conclusions, e.g. Prigogine theorists often model social formations and people as being so far far away from equilibrium that they (we) are continuously at the 'edge of chaos'. When I walk my door today will I find downtown Chicago out of equilibrium and or happily at the edge of chaos (Len Fisher and his 2009 *The Perfect Swarm*, comes to mind here). Only rarely will one hear a finger raised objection to these types of questionable statements. In 2005, authors Eric Schneider and Dorion Sagan, in their *Into the Cool*, ask, in question of the term far-from-equilibrium:

> "Is life a far-from-equilibrium system? If so, how far are organisms from equilibrium? And what does this phrase mean? In fact, the term *far-from-equilibrium* may be more applicable to backfiring engines than smoothly running life-forms."

> "Life is made up of [so] many reactions in the near equilibrium range [that it] may not be so 'far' from equilibrium as has been suggested."

(c) eoht.info/page/far-from-equilibrium

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16. (a) Note: this comment about "forces governing human interactions are likely to be electromagnetic" brings to mind the 2009 "Moriarty-Thims debate", during the course of which Irish physicist Philip Moriarty found it comical to believe that humans in marriage relationships are held together by the electromagnetic force.
(b) eoht.info/page/Moriarty-Thims+debate
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(b) eoht.info/page/Moriarty-Thims+debate+(part+three)

20. (a) Moriarty-Thims debate (2009), Comments #181.
(b) eoht.info/page/Moriarty-Thims+debate+(part+three)
