The architecture of thermodynamics and its future developments

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Introduction

Contemporary thermodynamics brings together hypotheses, concepts, data, measurements, etc. made at the microscopic level of the individual particles, and hypotheses, concepts, data, measurements made at the macroscopic level of the overall system. In addition, rules (mostly of statistical character) are stated to go from the microscopic level to the macroscopic level. The last information needed is the proportion between the size of the individual particle and that of the macroscopic system or, more simply, the number N of particles of the overall system.

In total, we thus have four places to discuss and possibly change the theory: - microscopic hypotheses, - macroscopic hypotheses, - rules from micro to macro, - N number.

Depending on the authors, these sets of hypotheses are presented differently within different « architectures » that we try to depict here. Our approach is of « philosophy of science » type and gives directions for research, that each would deserve specific discussion and computations.
**Abbreviations**

\( \text{Hm} = \text{hypotheses, concepts, laws... at microscopic level} \)
\( = \{ \text{space, time, mass, position, velocity, momentum, kinetic/potential energy, Newton laws...} \} \)

\( \text{Dm} = \text{data, measurements on individual particles} \)

\( \text{HM} = \text{hypotheses, concepts, laws... at Macroscopic level} \)
\( = \{ \text{heat, temperature, internal energy, entropy...} \} \)

\( \text{DM} = \text{measurements on macroscopic systems} \)

\( \text{HS} = \text{hypotheses, rules... to go from microscopic to macroscopic level} \)
\( = \{ \text{extensivity property; ergodic postulate; definition of microscopic states and numbering of particle cases: degeneracy of states, discernable/ non discernable character; equiprobability of microscopic states ...} \} \)

\( \text{DS} = \text{proportion between sizes of microscopic and macroscopic systems} \)
\( = N \) number of microscopic particles in the macroscopic system

\( \text{H} = \text{hypotheses, concepts, laws... on systems, whatever their size} \)
\( = \{ \text{mass, position, velocity, momentum, kinetic/potential energy...; heat, temperature, internal energy, entropy...} \} \)

\( \text{D} = \text{data, measurements on systems, whatever their size} \)

**Some possible architectures**
Architecture n°1

**Hm**
Hypotheses
Concepts
at microscopic level

**Dm**
Data, measurements
at microscopic level

Microscopic level
Mechanics

→

Macroscopic level
Thermodynamics

→ predictions

summation, averaging

Architecture n°2

**H**
Hypotheses
Concepts

Thermodynamics

→ predictions

(autonomous, universal, no scale)

**D**
Data, measurements
Microscopic level Mechanics

Macroscopic level Thermodynamics

(no HM nor DM)
and other possible architectures…

DISCUSSION

We prefer architecture n°3-1

Architecture n°1? - No: we also need data at macroscopic level, and also rules to go from micro to macro

Architecture n°2? - No, if one wants to relate thermodynamics to the rest of physics

Architecture n°3-0? - No, hypotheses at macroscopic level may be retrieved from the hypotheses at microscopic level together with the rules to go from micro to macro?

Architecture n°3-2? - No, we need information at macroscopic level

...
Can independent sets of hypotheses and data, both at microscopic and macroscopic level co-exist within a single architecture (n°3-0 or 3-1)? Will contradictions appear? Can we still decide independently the statistical rules and N number?

Several possible answers (matter of debate and of research):
- Hypotheses made at microscopic and macroscopic level are equivalent (they are not independent)
- These hypotheses are independent but complementary
- The hypotheses at micro and macro are both equivalent and different because of recursiveness aspects
- The hypotheses of statistical character to go from micro to macro (related to the value of N) can put up with the choices made independently at microscopic and macroscopic level (= internal degrees of freedom =)

Examples of recursiveness: - if long range forces do play (modify Hm) then Hs must be modified (no extensivity); - the value given to the mass of a particle depends on the values of all masses in universe (general relativity); - if N is small, Hs hypotheses must be reconsidered; - the use of $\Psi$ as in quantum mechanics links micro and macro; on the whole, we need micro to define macro, we need macro to define micro...

One consequence of recursiveness is the pluralism of theories.
Consequences

We can « arbitrarily » change (or discuss) some of the hypotheses made on Hs, Hm, HM, N; this will change the theory and/or this will allow us to understand the genesis of the concepts in the overall theory.

Examples:
- Discussion on Hm: discussion of space and time concepts → « time problem »: the first pb of time is not its irreversibility but its existence; understanding the construction of time and space → understanding the reversibility/irreversibility, equilibrium / non equilibrium pairs; the border between the terms in the pairs is not absolute but subject to arbitrary and uncertainty

- Discussion on the value of N → if N is small, Q (heat) and W (work) are not distinguishable, no thermodynamic concepts, no entropy. When N increases, the new thermodynamic concepts emerge from mechanics.

- Discussion on Hs: no extensivity → mathematical expression of S changes; different choices for the particle cases → different math statistics …
Selected references from the author


Guy B. (2011) Thinking space and time together, to appear, Philosophia Scientiae

Other references

The author has been inspired by works from many authors among which: Bedeaux, Beretta, Boltzmann, Fer, Carnot, Gibbs, Guillot, Jou, Kjelstrup, Lecoze, Lemarchand, Poincaré, Prigogine, Richet, Tondeur…

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