Introduction

In the field of science, it is sometimes the simplest and most general ideas that require the longest time to be recognized as valid.

Geology knew an example of this situation with the hypothesis of “Continental Drift”. Introduced by Alfred Wegener in 1912 [1][1], it was only in the 1960s that it was really inserted into teaching programmes and progressively improved under the extended concept of “Plate Tectonics”. Thanks to the numerous television shows now devoted to it, a geological process comes spontaneously to mind to anybody who looks at the schema shown in **Figure 1**. This is the idea that the continental areas separated by the Atlantic Ocean were unified in the past, and that the impression of parallelism given by their shorelines—although far from rigorous from the geometric point of view—is the residual clue to their separation.

In the period 1912-1960, things were not perceived in

[1] The numbers in brackets correspond to the papers cited in the References section.

Figure 1. Outline World Map.

that way because the implicit principle was at that time that the continents do not move. Several decades passed before the concept of continental drift was adopted and Wegener was already dead by that time, but his scientific fate was probably less dramatic than that of other pioneers of science. It is well known that, a few centuries before, Galileo and Giordano Bruno faced much greater difficulties when they tried to convince their contemporaries that, despite appearances, it is the Earth that moves around the Sun and not the Sun around the Earth.

Remaining in the context of the 20th century, the other great scientific hypothesis that has changed our habits of thinking is evidently the mass-energy relation $E = mc^2$, proposed in 1905 by Albert Einstein [2]. Although it is now universally accepted and thought to be indispensable in some specialties (astronomy and nuclear physics for example), there are other scientific fields where its role remains marginal and sometimes non-existent.

Thermodynamics is one of them and this peculiarity is associated with two others, constituting an interesting trilogy that can be summarized as follows:

- 1st Peculiarity: It is not inadvertently that the equation $E = mc^2$ is generally absent from thermodynamics textbooks, but because it is classically admitted that this equation seems unnecessary in this specialty and can therefore be deliberately omitted.
- 2nd Peculiarity: The main reason for this conclusion is that the theoretical predictions obtained by the conventional approach of thermodynamics are generally in good agreement with the results

experimentally observed. As a logical conclusion, the usual equations of thermodynamics are considered adequate.

- 3rd Peculiarity: Despite the relevance of this argument, it is a matter of fact that understanding thermodynamics is known to be difficult and this situation is mentioned in the preface of many books dealing with the subject. This is sometimes followed by complementary information saying that after some practice this impression disappears.

On this last point, the famous physicist Arnold Sommerfeld [3] was of a slightly different opinion, because when asked by his colleagues to write himself a book on thermodynamics—a work that in effect he carried out later—he replied:

"Thermodynamics is a funny subject. The first time you go through it, you don't understand it at all. The second time you go through it, you think you understand it, except for one or two points. The third time you go through it, you know you don't understand it, but by that time you are so used to the subject, it doesn't bother you anymore."

Other great scientists have felt the same. This was the case of Howards Reiss [4], who wrote in the preface of his own book on thermodynamics:

"*....The almost certain truth that nobody* (*authors included*) *understands thermodynamics completely. The writing of a book therefore becomes a kind of catharsis in which the author exorcises his own demon of incomprehension and prevents it from occupying the soul of another*"

This was also the case with Richard E. Dickerson [5], who wrote in his book on thermodynamics:

"*It is possible to know thermodynamics without understanding it*".

Besides the fact that these remarks are the sign of a respectable scientific honesty on the part of their authors, they can be viewed as invitations to think about the problem and try to participate in the search for a solution. The present very short book is an attempt in this direction. It rests on the idea that in thermodynamics, —as was the case evoked above for geology—conventional reasoning may include an inadequate premise, although it is commonly accepted. Referring to this possibility, the reader's attention is drawn to the followings three points:

- The premise suspected to be inadequate is the idea that the internal energy of a system undergoing a cycle (or of a system defined as isolated) is necessarily constant.
- To explain the alternative proposal, the idea that the internal energy of a system undergoing a cycle (or of a system defined as isolated) can vary, the suggested solution consists in inserting the mass-energy relation $E = mc^2$ into the thermodynamic equations.
- In this new way of thinking, it seems that thermodynamic theory becomes more easily understandable and the field of its applications can be extended.

A related point to be mentioned here is that the analysis presented in the following pages does not require that the reader be a specialist in physics or chemistry. It is accessible to every scientist who has a general base in thermodynamics and constitutes a condensed synthesis of several recently published papers that will be mentioned further. Although they do not seem to have been challenged, it is important to bear in mind that, for the moment, the suggested interpretation remains nothing but a hypothesis. It can be equally noted that equation $E = mc^2$ is currently the subject of renewed interest among a general public thirsty for scientific knowledge. Among the recent contributions going in this direction is the book “How to Understand $E = mc^2$”, by Christophe Galfard [6].

In memory of my wife, Annie

and for our children, Frederik, Isabelle and France