Preface

An engineer's approach to fundamental biology could well define the content of this book. I taught during 23 years theoretical disciplines of communication engineering at the Ecole nationale supérieure des Télécommunications (ENST) in Paris, especially *information theory* and *error-correction coding*; the latter was my main field of research. As a faculty member of a college of engineering, I limited my research activities to the engineering field. When I retired in 1997, I felt free to escape it and I undertook applying information theory and error-correcting codes to topics of broader significance, especially to biology. The reader will hopefully soon realize that, contrary to what may seem, there is a true continuity between communication engineering and some very basic biological problems.

The present book is thus a fruit of my retirement. My motivation for writing it was twofold. On the negative side, a sharp dissatisfaction about the trend of science towards increasing specialization, which results in its fragmentation into narrow subdisciplines which eventually become autistic to each others. Nothing prevents such subdisciplines to reach mutually incompatible conclusions. This situation makes extremely difficult to have a general view on science; even most philosophers seem to have given up. I think however, with Murray Gell-Mann, that 'it is vitally important that we supplement our specialized studies with serious attempts to take a crude look at the whole'. On the positive side, I think that information theory is as general and transdisciplinary as to help acquiring such a look and, moreover, that its use is mandatory in natural sciences, especially for understanding life.

My background is thus communication engineering. I nevertheless dare question biology and to some extent physics since I think that these sciences need the lessons of communication engineering and information theory, all the more they can be a strong antidote to their ever increasing specialization. Since I am not a biologist nor a physicist, my questions about biology and physics are naive. For lack of working experience, my knowledge of these sciences mainly relies on popularizing books. Such documents should be cautiously used and cannot reflect the latest researches. However, I compensate my lack of practical knowledge of these sciences, as far as I can, with my own experience. My position with respect to biology and physics is that of an observer from outside, similarly to that of a philosopher, except that my background in communication engineering hopefully provides usable concepts,

perspective and methods. This is a rather uncomfortable position. It turns out that letting biologists and physicists accept lessons from engineering is especially difficult. It may be a legacy of the Greco-Roman antiquity when engineering was the lot of slaves, while philosophy (including science in its modern meaning) was a noble activity of the free citizens. Prejudices are long-lived, so 25 centuries later science is most often perceived as creating ideas to be later exploited by engineers, while the upholders of 'pure' scientific disciplines ignore or refuse that concepts possibly useful to them could originate in engineering.

A major difficulty I met when I began writing this book is that information theory has never been adequately popularized, to a large extent because this is extremely difficult. Information theory is a mathematical discipline, hence basically abstract. Moreover its main object—information—is rather elusive. My first task has thus been to popularize the main topics of information theory which can be useful to biologists, and it is what I do in the first part of the book. The word 'information' has become very common and polysemic. Restrictions with respect to the usual meanings of a word are necessary for defining a scientific entity, and the definition I propose is not straightforward and rather abstract. Such lexical difficulties are unavoidable since a precise vocabulary is mandatory.

Besides attempting to popularize information theory, the remainder of the book intends to improve the understanding of the *living world*. At the light of information theory, mainstream biology is shown to inadequately account for the most important and specific phenomenon of life: *heredity*. Reconstructing biology in an information-theoretic perspective thus appeared to me as necessary, leading to a formidable research agenda as regards both the broadness of its scope and the amount of difficult work it demanded. Only a small part of it has actually been performed. This book can thus by no means be claimed to be exhaustive, but is hopefully forerunner. It could at best skim over the matter: introduce information theory as simply and intuitively as possible and merely deal with a few easy examples of its application to biology. I hope that it will prompt broader and deeper researches, at the risk of its own obsolescence. My first project was to also discuss a few applications to physics, but there was too much work still to be done, so I stopped at the border between the living and the inanimate. As I progressed in my writing, I discovered that many other topics were worth being dealt with so the completion of the book was for me a kind of horizon seeming to move back as I moved forward. No wonder if the finished book looks incomplete and calls for further researches.

In its part intended to popularize information theory, this book contains few formal proofs, which can be found in more technical works. However, everywhere it is possible, remarks are intended to help the reader to intuitively understand why the written statements are true. Such remarks cannot be substituted for formal proofs but, as based on them, hopefully show the logical necessity of the statements and their coherence.

No great efforts have been made to avoid redundancy. Besides being very useful in communication engineering, it has also the didactic virtue of helping the reader's understanding. I tried of course to avoid mere repetition and to present the same

concepts from changing points of view in order to hopefully provide more insight into them.

As a Frenchman, I have an easy access to documents written in my first language, and it is why the bibliography contains a rather unusual number of papers and books in French. No bibliography can be claimed to be exhaustive so, inevitably, it is somehow biased. In any way, besides prompting biologists to get interested in information theory and making their access to it as easy as possible, my project was to expound my own researches and not to objectively compile references. Most works referred to in this bibliography are those that I read when I wrote the book, but some of them are referred to because of their historical importance. Compilations like (Favareau 2010, Sloane and Wyner 1993, and Slepian 1974) were especially useful in this respect.

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