Science Writing and Beautiful Writing

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Can Science Writing Be Beautiful Writing?

The very title of this paper might sound unexpected if one views humanities and sciences as two separate, isolated, non-overlapping and maybe not even interacting domains. Within such prospective, beautiful writing, or any kind of pleasant writing, would belong to literature and, consequently, to the humanities domain, while science writing would belong to the other domain.

According to a rather diffuse commonplace, the way of writing and the mode of expression in science books and, even more, in technology books, is cool and dry. Consequently, reading those texts may be necessary, but not pleasant. On this basis, speaking of beautiful writing with reference to science writing might appear nearly impossible. On the other hand, if it were impossible, this would unavoidably imply the inference that science writing may be (i.e., it would be allowed to be) non-beautiful; this, in turn, would only be an elegant way to avoid saying the straightforward term ugly. But allowing science writing to be ugly writing would be a rather uninteresting, discouraging and altogether hard-to-accept conclusion. Therefore, the overall issue requires deeper reflection, examination and analysis. These three mental operations will have a major role in the current paper.

Reflection may conveniently start with a very basic, fundamental question: is it really necessary that science writing be cold, dry and, at the end, non-beautiful? In other words, are such characteristics functional to the requirements and to the objectives of scientific communication? In order to search for a well-founded and exhaustive answer, a number of issues and aspects need to be considered. They may be easily expressed in form of questions and grouped into two main categories, associated respectively with the two following perspectives:

The nature and purposes of scientific communication. What are its objectives? What need to be its characteristics in relation to these objectives? Are such objectives and characteristics better pursued within a non-beautiful or within a beautiful writing approach? Or, in
other words: Would it be possible that science texts be beautiful and pleasant to read? Which option would be more functional to the efficiency of scientific communication?

A historical perspective. Has science writing always been cold and dry? Is it always or univocally so in modern times? Discussing these issues will require a sort of excursus through the scientific and technical works of the past, taking into account both the features more closely pertaining to science writing and the aspects that make those texts examples of beautiful writing and attempting to identify relationships between the two. Though, for space reasons, such excursus is here bound to be rapid and to allow the consideration of only few relevant works, it will offer an insight that would hardly be possible otherwise.

These trains of reflection, often interacting and integrating with each other, will also highlight that the analysis/discussion cannot be limited to one of the two domains — either humanities or sciences. Language and the mode of expression, which are studied and refined within the humanities domain, play so deeply fundamental roles in the sciences that they may rightly be considered an overlap area between the two domains (Mammino, 1998). The way of writing is closely and inextricably associated with the mode of expression. Consequently, the whole discussion is bound to develop along borderlines and through overlap areas of the two domains.

Nature and Requirements of Scientific Communication

The main objective of scientific communication is the transmission of information in the clearest and most precise way. The text must enable the reader to understand the information completely and without risks of misinterpretations. This is true whichever the subject of the communication or the context considered — whether a paper for specialists or a textbook for students or material meant for a broader public. On the other hand, this is also true for any other type of communication, in any other area. What characterizes and distinguishes scientific communication is the fact that the information transmitted concerns aspects belonging to physical reality. Therefore, the way of being precise is determined by the characteristics of the portion and/or event of physical reality considered at a given moment. This aspect will be discussed more in detail in a next section.

Science communication utilizes language as its main tool. Language pertains to the humanities domain: within this domain, its structure is studied, its rules are codified, its historical development is analyzed and its nature may be discussed as part of the overall
philosophical investigation. Moreover, the communication-moment is in itself a literature moment. What we call literature is actually communication of a variety of things. Homer communicated very ancient legends, Lucretius communicated scientific models, and so on across centuries and across countries and cultures. Oral or written literature in the role of a communication form is probably one of the most widely-spread human activities. Like language, literature, too, pertains to the humanities domain.

Science writing is often denoted with terms borrowed from literature, e.g., when we speak of scientific prose. It is communication and, therefore, literature. It utilizes language — a humanities-bound tool. But its content consists of scientific information, i.e., information on physical/natural reality, gathered according to the criteria of what we call the scientific method. The only possible inference is that science writing, and scientific communication in general, constitute an overlap area between the domain of humanities and the domain of science.

In order to better pursue/achieve the objectives of scientific communication, the mode of expression in the sciences has specific requirements and characteristics that remain valid whichever the national language utilized. When we refer to these features, we speak of the language of science (Mammino, 1995). Its main requirements can be summarized as follows:

**Being rigorous.** This is the fundamental requirement. It has a deeper role, because it is related not only to the needs and purposes of scientific communication, but also (or even mainly) to the features of the scientific method and to the nature and limits of scientific knowledge. It is tantamount to extremely high precision in the way in which the information is transmitted. From a language (or expression) point of view, it implies that the choice of individual words, and of the way in which they are associated into sentences, be strictly consistent with the characteristics of the system or phenomenon described, and also with the type and level of knowledge we have about it. Since most words, including those of common language, acquire specific meanings and/or convey specific messages in relation to these aspects, words are hardly interchangeable in scientific communication.

**Being clear.** This requirement has the purpose of avoiding the risks of misinterpretations in the transmission of the information concerned.

**Being simple.** This requirement has the purpose of making communication easier, by enabling the reader’s attention to focus on the contents, without being engaged in additional efforts to interpret the literal meaning of sentences and texts (Mammino, 1995 & 1996).
All these requirements are functional to communication efficiency. Given the relevance of their roles, these requirements will also constitute fundamental reference-criteria for the reflections throughout the individual considerations and the whole discussion in this paper.

Practically-oriented questions become obvious at this point. How are the above-listed requirements realized in practice? What are the appropriate tools to this purpose? In searching for answers, one might consider what could be called the composition of a scientific text, in a chemical-wise meaning of the term, i.e., “what is it made of?” A scientific text contains a certain number of technical terms, i.e., terms denoting the specific objects and processes with which the given discipline is concerned. For example, ammonia, hydrofluoric acid, azeotrope are technical terms in chemistry; kinetic energy, angular momentum, dielectric constant are technical terms in physics; polynomial, differential equation, integral, are technical terms in mathematics; etc. However, in any scientific text, technical terms are, so-to-say, immersed in a “sea” of common words. These common words form and identify the core of each message in the communication: they constitute the key to each bit of information we want to transmit (Mammino, in press).

In terms of words and their association, conforming to the requirement of rigor implies:

**Correct usage of the technical terms.** This is nearly always complied with, probably on the basis of the general understanding (at the foundation of terminology as well as of languages) that each object has its name (Mammino, in press). Mistakes in the selection of individual technical terms are comparatively rare, even from the weakest students.

**Correct selection of individual common words and of the way in which they are associated into sentences.** This is often the determining feature: appropriate selection and association are condition sine qua non to the transmission of correct scientific information (Mammino, 1995 & 1996). On the other hand, they also constitute the operational ground to the purpose of making the expression beautiful.

Another essential feature for a text to be rigorous is the overall organization of the information to be transmitted. The main guideline in this regard is logic. Logic provides an imaginary thread for the appropriate mutual connection of the various pieces of information. It also offers guidelines to the selection of the appropriate tools provided by a given language in order to express the desired relationships between the individual pieces of information — e.g., cause/effect, hypothesis/thesis, relationships involving time, etc. (Mammino, 1995). On the other hand, adequate attention to the logic aspects of a text may
easily result in enhanced beauty. A text supported, throughout its whole extension, by a logical thread sustaining the development of thoughts and serving as a guide to the reader, is more pleasant to read and easier to understand. The lack of a logical thread, the incorrect sequence or incorrect logical connection between different pieces of information, make a text simultaneously hard to understand and generally ugly.

**Beautiful Writing**

The concept of beauty is not easily definable, because it is to a considerable extent related to individual perception. However, few considerations may help identify basic agreements on the more relevant features of beautiful language and, more specifically, of beautiful writing. The considerations that will follow refer to the kind of beauty that is associable — or can be integrated — with the requirements of scientific communication (other types of exploration into the generation or appreciation of beauty would go beyond the scope of the current discussion).

At first approximation, one might say that a text can be considered beautiful if reading it is pleasant. Rapid reflections to try and identify the “components” of being pleasant on reading will highlight that a text may be perceived as pleasant if the following conditions are fulfilled:

1. No particular difficulties are experienced in understanding its literal meaning.
2. It does not allow room for uncertainties in the interpretation, i.e., the reader can always be sure of what the author means and wants to communicate.
3. The reader’s attention is attracted, stimulated and maintained throughout the reading, i.e., the text would not be qualified as boring.
4. In practice, everybody knows when a text can be considered beautiful. When one enjoys reading a novel, or a well-built piece of literary criticism, one can perceive that their authors have devoted care to the beauty of expression and to making communication attractive.

What are the ingredients that are fundamental for a text to be beautiful? It may be more convenient to consider them from the writer’s point of view. Then, they are the following:

1. **Conformity to the concept/s to be transmitted**, by an appropriate selection of the individual words and of the way in which they are associated to build sentences. This means choosing the best words and their best assembling, so as to ensure that the reader may understand the message clearly and completely, and to exclude the
risk that he/she understands something different (what would amount to bad communication). It is also the basic condition for being precise, since it demands the association, to each concept, of expressions and/or formulations that represent and transmit it completely (unclear, imprecise language may distort messages and concepts). The reverse is also valid: when a concept/message is expressed in a correct and understandable way, it means that the words have been selected and associated properly.

Conformity to the grammar and syntax rules of the language utilized. These rules constitute a sort of general code for the expression in the given language, the most recent outcome of the historical development of that language. They are, therefore, a set of formal requirements, complying with which is necessary to make the communication fully understandable.

Each of these ingredients is a necessary condition, but, taken alone, it is not sufficient to make beautiful language. On the other hand, their combination may already result in sufficiency.

Of course, there might be something more than mere sufficiency, in a beauty scale. This will be the outcome of a number of components in the author's general preparation, and is related to the depth and richness of his/her cultural baggage. The more one knows, the more one might express things in an attractive way, above all if this knowledge is not restricted to a single area, but extends to interface and overlap areas, at least to those bordering with one's own specialization field. Such extended vision enables the perception and transmission of a broader and richer picture about the issues of interest, what, in turn, may be perceived by the reader as attractive and/or beautiful. In addition, the more one knows, the higher the probability to achieve a high degree of clarity and simplicity in expressing things, which, in turn, makes reading more attractive and pleasant. On the other hand, attention to traditional aspects of expression-beauty like, e.g., the harmony of individual sentences and of the overall layout, or even the sound of words and sentences, may contribute to enhance the beauty of the text.

Besides the factors just considered, there may be components related to a person's innate abilities. These are obviously beyond the possibility of analysis in terms of "ingredients." The factors just considered may enable a good level of beauty and, simultaneously, of communication effectiveness. Exceptional levels would add something that is not easily classifiable.

A comparison of these ingredients with the requirements of the language of science discussed in the previous section easily highlights a high degree of correspondence — the basic tools to pursue rigor and the basic tools to pursue beauty are the same. This does not mean that,
once a text is rigorous and clear, it is also automatically beautiful. However, it does mean that a non-rigorous text, being imprecise and conveying imprecise information, cannot be perceived as beautiful. Likewise, an unclear text, being difficult to understand, cannot be perceived as beautiful.

Beauty adds something to rigor and clarity. That something enhances communication effectiveness by making it attractive. Therefore, it is worth pursuing. Simple considerations may suitably illustrate this statement. There have been tendencies, above all in the XX century, under-estimating the role of being attractive in science writing. This has resulted in an impoverishment of part of modern scientific prose. One aspect of such impoverishment is that the sentences and explanations between equations and formulae (in mathematics, physics and chemistry books) are not given adequate care, thus resulting rather unclear. In this way, the conceptual connections between the strictly physico-mathematical components, and/or the numerical bits of information, became inadequate. Consequently, the overall logical thread gets loose or disappears. As a final result, communication disappears, because of lack of clarity and of the consequent reader’s fatigue. Reading such material becomes a hard task that students and even specialists try to avoid. The content of the material may be interesting, but its communication is interrupted, or poorly effective, because of inadequate attention to endow it with at least a basic level of beauty.

For the discussion to be complete, the role of rigor in literature works should also be considered. It was previously inferred that precision is a necessary condition for beauty. On the other hand, there is a diffuse tendency to mechanically associate the concept of precision with science writing and that of beauty with literature writing — such mechanical association being part of the rather frequent dichotomy relegating humanities and sciences to mutually isolated, non-interacting and non-overlapping domains. The previous discussion would immediately stimulate the question: “Is precision a requirement of literature writing?” The obviously positive answer would, in turn, stimulate the question: “What then differentiates science writing from literature writing, if they have the same fundamental requirements of being precise and clear?” The difference consists in what we may call the reference system for precision.

In a literature work, the author expresses perceptions about something, or builds and depicts images of characters, places and events. All these features are the author’s production: he/she is free to imagine and build them in the way he/she considers more suitable. When he/she wants to communicate their descriptions to the reader, he/she tries to do it in the most effective way, with all the wealth of information that may be necessary for the reader to perceive a
description that is as close as possible to that imagined/elaborated/wanted by the author. The author’s mental image constitutes the reference term, and precision becomes a tool for an effective transmission of this image and all its individual details. Precision is pursued by mastery use of the possibilities offered by language. For example, in the following description of old Miss Marple’s reaction (Christie), precision is attained through a set of subsequent specifications: And then in a nice, old-fashioned, lady-like, maiden-lady way, she blushed.

In the case of science writing, the reference term is a system or a phenomenon belonging to physical reality. Its characteristics constitute the constraints determining what is rigorous and what is not. An additional constraint is set by the way in which, and the extent to which, we know the system or the phenomenon considered. The selection of words and sentences is guided/controlled by these constraints.

The Birth of Science Writing in Europe.

As mentioned at the beginning, a brief historical excursus is essential for a better insight of the options and practices through the development of science. The word science itself may be given different interpretations, depending on the criteria adopted to define its domain. In the current context, it is utilized to denote investigation processes and activities aiming at, and resulting in, the proposition of models of physical reality, with the investigation making use of observations and of theoretical elaboration/reflection and being capable of discussing the approach/es adopted.

Science was born within philosophy. This was fully consistent with the vision of the world and of human knowledge in ancient Greece. Philosophy, literally, the love of wisdom, implied the love of knowledge. Therefore, it included all the areas that can offer objects of investigation to human mind. Most of the questions to which science has, since then, tried to find answers, were first proposed in those times, as interesting themes for the inquiring mind. The first texts describing observations about systems and phenomena, and attempting to interpret those observations by proposing suitable models, are found within the works of ancient philosophers.

According to the traditions of the Greek environment, philosophers had to be experts in dialogue, in debating, in expressing their hypotheses and theories in an elegant and convincing way. This was particularly important in a context in which all hypotheses, theories and conclusions were open to free debate, not only within the schools and/or by the philosopher’s students/adepts, but also in the squares and by the public. In addition, the association of the concepts good and
beautiful, so relevant in the Greek culture, required that the presentation of theories and models be harmonic and beautiful in order to be perceived as positive, valid and, in the end, in order to be convincing. For all these reasons, the philosophers’ mode of expression was both precise and rich: they had to know how to utilize and master all the tools made available by language, in order to convince the listener or the reader. Science writing, as part of philosophy writing, had to be beautiful for its contents to be appreciated. The Greek ideal of beauty implied harmony. In the case of philosophy writing, it implied a harmonic development of thoughts, with a flowing logical thread guiding it, without jumps that would make understanding difficult or reading unpleasant. This resulted in a constant rigor throughout the texts. In other words, the pursuit of harmony resulted in the most fundamental requirement of science writing.

An example concerning individual terms may conveniently illustrate the previous statements. The rigorous use of terms, following their rigorous definition, is an essential component in complying with the requirements of the language of science. It is also essential in the development of a well-organized and clear presentation or discussion. Terms are defined within models and/or contexts. For example, the meaning of the term system is different as the subject-context changes: it has one meaning in physical sciences, another in architecture, another in physiology. In science communication, it is always important that the reader/listener knows the precise meaning of terms within the context of interest. Clear definitions are functional to the clarity of the entire discourse. When Plato presented his model of physical reality, based on the hypothesis that two types of triangles are the foundation of elements and substances, he took care of the rigor of all the details. In doing so, he also analyzed the meaning of terms belonging to common language, prior to utilizing them in the philosophical/scientific discourse. The analysis attempted to relate direct experience to his model and resulted in definitions that became part of the model. E.g., he relates the meaning of the adjective “hot” to the properties of fire (Plato, XXVI): First of all, let us analyze what we mean when we say that fire is hot: and we can reason on this point on the basis of the dividing and cutting power it exerts on our bodies.

Technology writing developed in the same period. The most relevant technical texts of ancient times were written in Latin by Roman specialists. Such texts, though providing all the technological details in the field of interest, were enriched with formal beauty to attract and convince their readers. Probably the most complete and best-organized text, from the point of view of the transmission of technical information, is Vitruvius’ De Architectura (On Architecture). It is a technology work, describing and discussing construction techniques for various types of buildings and all the related aspects,
from the characteristics of materials to the criteria for the best selection of drinkable-water sources. It is simultaneously a scientific work, because it explains the various aspects of the technical information in terms of the scientific models of that time. It is also a work having great literature value, easy and pleasant to read. The objective of being clear is stated explicitly (Vitruvius, II): *Now I will go back to what I had proposed and I will talk, in a way that is clear to the reader, of the materials that are suitable for the construction of buildings, of how it seems that they have being originated by the nature of things ....*

The pursuit of clarity became a paramount factor in making the mode of expression pleasant, thus contributing to the overall beauty of the text.

**Poetry as Science Writing**

A text may present new observations, hypotheses, theories, models, interpretations, etc., to the readers’ attention. In this case, it would be a science work. Other texts may have a different aim — that of explaining already existing models and theories to the layman or to the new generation. These texts have a pedagogical objective, i.e., they aim at teaching.

Most writings of ancient philosophers had an inherent pedagogical component. However, there have also been works more specifically aiming at teaching a certain model, or a certain set of views on nature, on cosmology, etc. In ancient Greece, the tradition of such pedagogical writings started with Hesiod. It is interesting to note that most of these works were written in verse. In other words, poetry, the highest form of literary expression and/or the form capable of attaining the highest levels of beauty, was considered the optimal medium to transmit scientific knowledge, when the transmission had mainly teaching objectives. The option of utilizing beauty as a pedagogical tool may stimulate a variety of interesting reflections also for our modern contexts. Some of them will be briefly outlined in a next section.

The most famous educational work of European antiquity is also one of the most beautiful poems of Latin literature, Lucretius’ *De Rerum Natura* (On the Nature of Things). The poem teaches the most valid physical model of antiquity — Leukippus’ and Demokritos’ atomistic theory, within the framework of Epicurus’ interpretation. Poetry in itself is beautiful and convincing. The features that were common in the poetry of those times, like the use of similitudes, became effective instruments to convince the reader about the reasonability and validity of the atomistic hypothesis and of the whole model that can be built on it. Actually, poetry eased one of the most difficult tasks in science communication — the introduction of new
hypotheses in association with a new interpretation model. The difficulty is greater if such hypotheses contradict already established models or are not associable with common experience in an easy and straightforward way. Through history, such difficulties were encountered on several occasions, e.g., for the introduction of the Copernican heliocentric system in the 17th century. In modern times, the latter aspect — i.e., the associability with common experience — is not relevant at scientific level, but it still has educational/pedagogical relevance, in association with the introduction, to pupils and students, of hypotheses and models whose features are not close to every-day life experience.

In Lucretius’ times, the atomistic model was in contradiction with the most widely accepted model, based on Aristotle’s hypothesis of the continuity of matter. Moreover, the features of the model cannot be straightforwardly deduced from common experience. Therefore, the presentation of the hypotheses serving as foundations to its whole conceptual framework had to be particularly convincing. Lucretius’ approach contained highly valid pedagogical features. He chose to support the hypotheses with images of every-day life, to stimulate reflection on their significance and to guide the reader to the desired inferences. The images depict scenes that were surely familiar to the reader. They are described with the lyrical beauty of high poetry, what attracts the reader, enables him/her to enjoy the picture evoked by the verses and generates an overall amiable and pleased attitude. On the other hand, they are selected and analyzed with the rigor of a scientist (or of a philosopher, for those times) to an extent that would be consistent with the strictest criteria of our epoch. Rigor, embedded in beauty, finalizes the task of convincing the reader.

The consideration of some of these images (Lucretius) may serve as convenient illustration. The translation cannot transmit the musical rhythm of the original verses, because this, though very important to the overall communication transmission, belongs to the language in which the poem is originally written. However, the translation still allows to perceive the beauty of the images and of their descriptions (in terms of choice/use of words) and, at the same time, the rigor of the analyses. The initial difficulty to be addressed was related to the fact that atoms cannot be seen: “But maybe you might doubt the things I am telling you, because atoms cannot be seen by our eyes ...” (xx). However, there are other things whose existence we take for granted, but that cannot be seen: “However, consider which other things are there, whose existence we have to acknowledge, but that cannot be seen. The violence of unleashed wind upsets the sea, destroys big ships and moves the clouds .... Winds, therefore, exist, though they are invisible bodies” (xx). Once the reader has been guided to accept the possibility of things that we do not see, he/she is ready for the next
step of the discussion: the consideration of the question whether it is
reasonable to assume that there are extremely small particles of the
various substances. Everyday experience, if deeply analyzed, suggests
that it is reasonable. Lucretius recalls a number of processes for which
our senses can only perceive the outcome, but not the individual events:

In the course of many years, a ring worn on a finger gets
thinner, water dripping on a stone digs a hole in it .... We
see the stones of the road pavement being consumed by the
feet of the people walking on them. The bronze statues
near the town gates show their right hand made thinner by
the frequent touches of travellers greeting them while
passing by (xxx).

At this point, the interpretation follows smoothly from the
logical trend of reasoning: each individual action (each movement of
the finger, each drop of water, each step of walking person, each
greeting-touch on the god's statue hand) must remove some small
particles, so small that we cannot see them: "We see that all these
things diminish as they are consumed. But jealous nature has prevented
us from seeing which particles come off and in which moment" (xx).
Once the main hypothesis has been made acceptable, the model can
develop into a logical construction providing interpretations of natural
facts and events. The development continues utilizing examples from
every-day life, guiding the reader's attention through the rigorous logic
of the discourse and simultaneously attracting and maintaining his/her
attention, and making reading pleasant, through the beauty of the verses
and the images.

**Beauty as an Option to Protect Scientific Secrets**

The works mentioned up to now, and most of the other works of
antiquity, associated expression *beauty* to the criteria we consider
essential for modern scientific communication, i.e., rigor, clarity,
overall effectiveness. They concerned the domains of physics, of the
models of matter, of natural sciences, of technology. However, there
was another science, still in the process of being born, still enclosed
within the domain of mystery and bound by the requirement of secrecy
— that was alchemy, the ancestor of modern chemistry. There is
literary beauty in the fantastic, allegoric images under which the
ancient alchemists masked their chemical knowledge and recipes. Their
communication was to be understood only by the initiated, the secrets
could not be revealed to other people. Beautiful allegories became tools
to protect/insure secrecy. The texts are difficult, or nearly impossible,
to understand beyond their literary meaning, if one does not know the
key to interpretation. However, reading them may be pleasant, both for
the richness and beauty of their images and expressions and for the way in which they represent a fundamental thread in the approach to the study of substances, evolving from ancient Egypt through the Hellenistic period, flourishing within the Arab civilization and finally reaching Europe.

An example of allegoric alchemy writing is offered by the following parts of a text by a Greek alchemist of the 3rd century of our era (Holmyard):

Then up there jumps a dragon who, when exposed to horse manure for thirty days, devours its tail until nothing of it remains ....

When it was born, it rose from the hot and humid substance of united things. The tight embrace of the male element and the female element — a union which took place in the sea — generated this dragon ... (xx).

A “translation” into modern chemical terms would be:

Then an alloy of copper and silver is formed, which, after been kept warm in horse manure for thirty days, does not show any visible trace of copper or silver ....

The alloy was prepared by heating the copper and the silver together with mercury ... (xx).

The alchemical text is definitely much more poetic than the corresponding chemical recipe in modern words. However, it would be much more difficult to follow its instructions in a laboratory or in a factory! As chemistry developed from alchemy, the requirement of secrecy necessarily faded away, substances and operations started being called by clearly and univocally defined terms, and chemistry writing entered into the main stream of science writing.

Science Writing after the Middle Ages

With the awakening of European science after the Middle Ages, the writings of the new scientists embedded the spirit of search and the explorations by inquiring minds. The inquiring attitude is in itself a source of beauty. The reader is guided along the whole thread of thoughts followed by the scientist, is stimulated to share his doubts and to evaluate the validity of his suggestions and hypotheses. The outcome may be a literature work. For example, Leonardo’s discussion about the
origin of fossils is a scientific text for its theme, but it also pertains to Italian literature, because of its value as a written text.

Galileo’s works are probably among the best examples of expression—beauty in scientific texts. They belong to the history of science and to the history of philosophy for their contents, to the history of Italian literature for their beauty. He introduced and/or supported new hypotheses about a number of aspects of physical reality, from the Solar System to the laws of motion and to gravity. As already mentioned, such an operation demands that the scientist be particularly clear and convincing. Galileo adopted the dialogue option. This is the option pertaining to the literature-area characterized by the most immediate type of communication, i.e., theatre/drama literature. In Galileo’s works, it contributes to the purpose of making the scientific discussion accessible to the reader in a way that is simultaneously easily understandable and involving. It also contributes to address another type of features whose communication is particularly difficult, i.e., those pertaining to the scientific method. The difficulties are associated with a number of factors inherent to a discourse on the method and can be summarized as follows:

The considerable degree of abstractness and the associated considerable degree of generality. Thinking in general terms is often perceived as more difficult than thinking in particular ones.

The fact that the discourse involves aspects typical of philosophy as well as aspects typical of science, thus pertaining to an overlap area between the two domains (humanities and sciences). Therefore, even a basic-level approach to the theme requires an interdisciplinary background and attitude.

The mode of expression. Philosophers who investigate the method of the sciences often use a highly specialized language that is fully adequate for communication to other specialists. But, when the information is to be communicated to other readers, including students, a full transmission of the concepts is not easy. How to make the reader fully perceive the complexity of concepts like those concerning the nature and limits of our knowledge, or the fact that these limits are strongly linked to the historical context, but are also related to chance, to the occurrence-possibility of events leading to a certain discovery? Even the very wording through which the previous sentence is
formulated may not convey a real meaning to a reader that is not very familiar with the discourse on the method.

Galileo was the founder of the modern scientific method. Thus, his presentation of the aspects and features of the method had to be very clear and convincing, both because of the nature of the discourse and because he was introducing new points of view and new approaches. The dialogue option proved very functional to this purpose. Other tools strengthened the possibilities offered by dialogue. It may be worth considering an example to better illustrate these aspects. For a more complete understanding of the example, it may be useful to preliminarily recall that the domain of the things that are still beyond our scientific knowledge involves two main categories:

Things, for which we are aware that we do not know a number (or even a great number) of aspects. For example, we are aware that we do not know many aspects of the mechanisms through which cancer is generated and develops.

Things whose existence or possibility is not even imagined at a given stage. A convincing example is offered by the history of the atomistic model. The model of the ancient Greek philosophers was self-consistent and, probably, the most complete that could be developed within a purely mechanical approach. But those philosophers did not know (they could not even imagine) an essential feature — the electrical nature of the particles constituting matter. Once this feature was discovered, towards the end of the XIX century, the model could develop to reach much more sophisticated levels of formalization and interpretation.

Galileo presents this ensemble of concepts through a literature instrument: an apologue in which an easily understandable story develops through a set of images expressed in lyrical terms while transmitting a complex and fundamental message (Galileo):

In a very solitary place, a man was born, gifted by nature with a very sharp intellect and an extraordinary curiosity. He grew various birds for his fun, and he much enjoyed their songs and with great surprise he used to observe by which beautiful means they could form different songs, all of them very melodious, at their will, by using that same air that they breathed.

It happened that, one night, he heard a delicate sound near his house and, not being able to imagine that it might be anything else, other than another bird, he moved out to catch it. And, once in the road, he found a shepherd boy who was deriving those different voices,
similar to those of a bird, but with a very different manner, by blowing into a certain hollow piece of wood and moving his fingers on it — now closing and now opening the holes that were in it (xx).

He bought the instrument, and the event provoked reflections:

... and realizing that, had it not been for the chance of the shepherd boy passing by, he would never had learnt that there were in nature two ways of making beautiful sounds and songs, he decided to go away from home, thinking he might meet some other venture by doing so (xx).

He next hears the sound of a violin and reflections develop further: "... having met two new and so unexpected ways of making voices and songs, he started thinking that there might be more in nature" (xx). He continues discovering sources of sounds and, in the process "... the certainties he had about knowing how sound is generated would decrease" (xx), until, at the end, "... he became so cautious about his knowledge that, when asked how sounds are generated, he freely responded that he knew some ways, but he was definitely sure that there might be hundred more unknown and unthinkable" (xx). The reader, too, becomes convinced of the variety of possibilities that can open to an inquiring mind. Such conviction has an internalization valence that would neither be generated by simple statements like "there are lots of things that we do not yet know" or "science needs to be considered through a historical perspective," or similar others, nor by an elaborated philosophical explanation. The literature tools have achieved the purpose of making complex concepts be perceived as understandable and be internalized as would-be familiar.

The interest in technology was one of the relevant components of the new interest in sciences. Scientists stated clearly that technological procedures contain a wealth of information that might open new insights to the study of several aspects of nature. Meanwhile, some specialists took care of organizing the technological knowledge available in certain areas, in order both to provide reference material to other specialists and to call attention on the variety of aspects involved in the given technological discipline, on all the factors contributing to its dignity as a human endeavor. The latter objectives required the writer to attract and maintain the attention of the reader and, therefore, to offer him/her something that is easily understandable and pleasant to read, even when the reader is not himself a specialist in the area. In this way, some of the technological books were written with a care that conferred them literature valence. Particularly relevant examples may be George Agricola’s De Re Metallica (On Metals) and Andrea
Palladio’s *I quattro libri dell’Architettura* (The Four Books on Architecture).

**Science Writing in Modern Times**

In the last four centuries, science has become increasingly more specialized, first with a clear-cut separation of different subjects and, subsequently, with the identification of different areas within each subject. Through the XX century, the number of specialization areas has increased enormously, while the average range of concern of each area has narrowed significantly.

Scientific communication from specialists to other specialists in the same area accounts now for a good deal of the overall scientific literature. A quick look to any scientific journal will show that, with few exceptions, such communication does not pursue any goal of being *beautiful*. It responds to more or less standardized formats. The fact that its contents can be rarely understood by persons who are not specialists in the given area is probably an important reason for the lack of attention to formal beauty. The authors know that, in any case, their fellow specialists will understand their communication, while nobody else would really possess the tools to do so. The assumption that specialists will read it as part of their work-duties and their scientific interests, not in order to find the reading attracting and pleasant, further decreases the pull for the communication to be attractive. How much may be lost in terms of communication-effectiveness, or even in terms of creativity-stimulation, is probably impossible to evaluate.

It would appear obvious to assume that other forms of science writing — above all, books writing — should not be affected by the impact of specialization in the same way, or to the same extent, as papers-writing. Books, or articles meant for the public, need to be attractive to the reader. On the other hand, the habit of not paying attention to text-beauty, acquired on writing for specialized journals, does not always disappear when the same person writes for a broader public. Then, the book or the article is not easily readable or understandable. It is not attractive. As a consequence, the reader gets tired and does not read it. The result is the failure of the information-transmission. Altogether, the fact that a number of science texts are not attractive (are not even meant to be attractive) may be responsible for the fact that many young persons consider science too difficult and non-attractive. It appears easy to hypothesize that, if reading science books were more easy and pleasant, more persons could develop a comfortable familiarity with the different sciences, their models, their ways of proceeding and their great wealth of information.
The mechanisms described above may be at least partially responsible for the impoverishment of part of modern scientific prose. It would also be interesting to consider whether, and to which extent, the increased perception of humanities and sciences as very separate domains might have contributed to the perception (or assumption) that text-elaboration in the direction of beautiful language pertains only to humanities and that science prose is somehow allowed to be ugly. In most recent years, an additional phenomenon may contribute to the poverty of part of scientific prose — the general deterioration of linguistic knowledge, and of the associated abilities, that is affecting most countriescontexts. It is still difficult to evaluate its consequences on science writing and, even more, on scientific creativity itself. Language is a fundamental instrument of thought. It is therefore obvious to infer that an impoverishment in language-mastering is bound to result in a corresponding impoverishment in thought-creation. The issue deserves sophisticated analysis, which would — however — go beyond the scope of the current discussion.

Of course, not all the science works of modern times suffer from the negative qualities described above. There are numerous examples of high-quality, beautiful texts. Some of them were written by the great innovators of scientific thought and/or by great scholars, like those by Albert Einstein or by Levi Civita. The fact that the greatest scientists often write in a definitely beautiful way may in itself stimulate interesting reflections. Technology writing also shows beautiful works. For example, the Italian civil engineer Pier Luigi Nervi used a very concise, but highly expressive and suggestive language, associating high content-density with expression harmony through masterly use of the language instrument. The Spanish civil engineer Eduardo Torroja wrote a number of works that approach the characteristics of literature masterpieces, while presenting and discussing highly specialized themes in the theory of structures.

**Some Additional Considerations and Reflections**

The reflections presented in the previous sections developed mostly within the two major perspectives mentioned at the beginning — the perspective focusing on the roles of language in science communication and the historical perspective. However, there is a variety of other possible reflections-trends that relate to the theme of the current paper. Some of them will be briefly considered in this section, within a sort of “miscellaneous” selection. These different issues are not linked to each other by a linear-type thread, but they all contribute significant details to the general picture, thus making the overall ensemble of reflections more complete.
The Writer and the Reader

Throughout the previous discussion, attention was devoted to the point of view of the reader on some occasions, to that of the writer on some others. The relationship between these two perspectives can be viewed as a sort of provider-user relationship, whose main features can be summarized in a basic, very schematic way. The position of the reader is the position of the user, whose basic attitude responds to the following criteria:

If a text is well written, one enjoys reading it and is willing to read it. If it is badly written, one does not enjoy reading it and is not willing to read it.

If a text is written in a clear way, one understands its content, if it is written in a bad way, one does not understand it.

On this ground, the more a writer wishes to communicate something, the more he/she needs to aim at providing a good, well written and enjoyable text. For science communication to be effective, good writing, beautiful writing need to be relevant features of science writing.

Building the Foundations for Good Writing

Once good, beautiful writing is acknowledged as a recommendable objective, it becomes important to develop the ability and the habit of doing it. The following components can play fundamental roles to this purpose:

Being convinced that writing well is important. Alongside with the previous considerations, one’s own experience as a reader may enhance the awareness of such importance.

Learning to master the language as an expression tool, to know and be able to utilize all its potentialities. Language is the main tool to precision, to rigor, to clarity and to beauty. It is essential to learn how to utilize it well, just as it would be the case with any other tool, for any other purposes. Reading provides the best training. It may be complemented by some philological studies — at least of one’s own language — to enhance the awareness of the possibilities offered by the given language for the expression of details, relationships, nuances.

Achieving a deep understanding of the theme/issue about which one is going to write. It is impossible to write well about something, if that something is not clearly and completely understood. Thorough
understanding is so essential a condition that needing to write may constitute sufficient motivation for efforts towards better understanding. Understanding well and writing well may also become two mutually enhancing objectives: one tries to understand better in order to be able to write, and the attempts to good, beautiful writing demand continuous improvements in the level of understanding. This mutual enhancement provides the basis for options utilizing science-writing as a pedagogical instrument aimed at facilitating conceptual understanding in the sciences (Castro).

**Beautiful Writing as a Feature of Pedagogical Approaches in Science Teaching**

While considering Lucretius’ work, two general features of his educational approach were specifically underlined, namely:

- The association of beauty and rigor in the reasoning trend and in its expression.

- The utilization of images familiar from everyday life, in order to make the transmission of scientific information more concrete and more easily perceivable by the reader/learner.

The latter feature is the object of active investigation by science educators (e.g., Pinto Cañon). The former feature has not so far been given particular attention. However, the considerations developed in the previous discussions suggest the opportunity of deeper reflections on the pedagogical effectiveness of the rigour + beauty combination. The design of corresponding practical options might consider diverse pathways, from the utilization of the most beautiful forms of literature-expression to facilitate students’ approach to the sciences, to various ways of inviting students to write in order to enhance understanding.

As mentioned previously, reading good texts is essential to acquire good writing abilities. In order to utilize the rigour + beauty combination it is therefore necessary to encourage students to read well written science texts. The works that can be considered classical in science literature (works by prominent scientists throughout history, including modern ones) constitute the best choice to familiarize students with good-level science writing. Reading these works will be beneficial both to science students and to non-science students.

In the case of science students, looking into the history of science and reading at least some of the classical works in the area of interest, will offer the double pleasure and advantage to come to know
the trend of reasoning that has led to modern models and to enjoy beautiful scientific prose. Adding the reading of good literature works will enhance the familiarity with correct and beautiful use of the language, and will broaden the students’ general culture. When writing (answers to tests and assignments, laboratory reports, essays, course-projects, etc.), the habit of paying careful attention to the mode of expression — to the appropriate selection of individual words and of the way of associating them into sentences — will contribute to the overall correctness of the answers and/or descriptions. Such attention demands clearer and deeper understanding of concepts, because one can express something in a clear and harmonic way only if that something is clearly and completely understood. Therefore, attention to the expression aspects can be a route to better conceptual understanding. It may be added that high-quality forms of expression are not unavoidably beyond a students’ reach. Alberto Cavaliere’s success is a significant example. In 1923, still a university chemistry student, he failed his general-chemistry examination in the June session. So, he had to work again on the same material, to prepare for the September session. In order to make this work less boring and more stimulating, he re-wrote the whole material in verses. At the September exam, he answered each question with an appropriate set of verses, containing all the necessary information expressed in a rigorous way. His astonished lecturers had to give him maximum marks. Moreover, his general-chemistry poem was published, and it has since enjoyed several editions (Cavaliere).

In the case of humanities students, reading science classical works — at least, those works that do not require too advanced specialized knowledge — would offer the opportunity of appreciating the logic and rigor of their expression. It would also help acquire deeper familiarity with reasoning and expression rigor, what is important in any type of intellectual and professional formation.

Teachers can encourage and guide these activities. Science teachers can utilize the attention to expression aspects as a powerful tool to enhance conceptual understanding — e.g., by stimulating students to appreciate rigor and clarity in the mode of expression or by highlighting the role of individual words and of their association in the transmission of correct scientific information (Mammino, 2000). They can also highlight the combination of scientific rigor and expression beauty in selected parts from science classical works, thus contributing to the development of open and inquiring minds. Humanities teachers can include pieces from scientists’ works in their readings selections and highlight their formal beauty in association with the communication rigor, what will help students develop a broader view of human activities as well as a sort of familiarity with the sciences that will prevent them from viewing sciences as an alien domain.
Beauty and Quantitative-Based Readability

It was mentioned more than once that a beautiful text is easy to read and to understand. Some temptations might arise to associate this concept to some of the readability criteria formulated for various purposes. A simple analysis would show that such an association is not possible.

Readability criteria are often quantitative criteria, counting the number of words per sentence and/or the number of syllables per word. Beauty, the possibility of a text to be enjoyable, are qualitative features, not reducible to a threshold number of syllables or words. They imply much more. A sentence could be hard to understand, or unattractive to read, even if it is short and it consists of short words. On the other hand, a well-constructed, logically fluent sentence can be easy to read even if it is long. If, in addition, such sentence contains properly chosen words, it can be attractive and beautiful.

As mentioned previously, being simple is one of the requirements of the language of science. However, it is important to clearly distinguish between being simple and being poor. Being simple means that the literal meaning of the statements and/or descriptions can be understood on reading, without this requiring particular efforts. This goal can be attained even by using a rich way of expression, fully utilizing all the potentialities offered by the given language. On the other hand, a poor way of expression may be simple, but it would also unavoidably be unattractive and boring: it would definitely be far from beautiful. Therefore, though being simple, it would not be communication-effective.

Space reasons do not allow a deeper discussion of these aspects in the current context. However, the above considerations may be sufficient to suggest the amplitude of the variety of features and components that may contribute to beautiful writing, and to show the impossibility of reducing it to simple quantitative criteria. An additional reflection may serve as appropriate closure to this section. The richness and beauty of the mode of expression is an important heritage in human culture. This concerns also science expression and science writing. Several works of the past and of the XX century have established a tradition of beautiful, enjoyable science writing. It would be a pity to interrupt this tradition through the impoverishment of language and expression. Moreover, such impoverishment might affect scientific creativity in ways that it would be difficult to predict now, but which might turn out to be fundamental ones.
Discussion and Conclusions

Science writing can be beautiful writing. The requirements of the language of science associate easily with the features capable of generating a perception of that type of beauty that is based on harmony. Moreover, being beautiful increases communication effectiveness. The more the way of expression is precise, clear and enjoyable for the reader, the higher the extent of understanding and the level of interest developed by the reader. The history of science highlights the communication and pedagogical values of beautiful writing.

Pursuing expression quality and beauty in a science text can be viewed and utilized as a pedagogical tool to enhance conceptual understanding both from students and for science communication to a broader public. The design of new options to this purpose constitutes a challenging area for exploration and investigation.

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